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HOW IT WORKS

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CANAL BOATS AND CLEVER LOCK PHYSICS

SECRETS OF DARKROOM PHOTO DEVELOPING

WHY THIS CONTROLS YOUR LIFE

HOW THE 'MASTER GLAND' DECIDES WHEN YOU'RE HUNGRY, HAPPY AND EVEN HOW BIG YOU GROW

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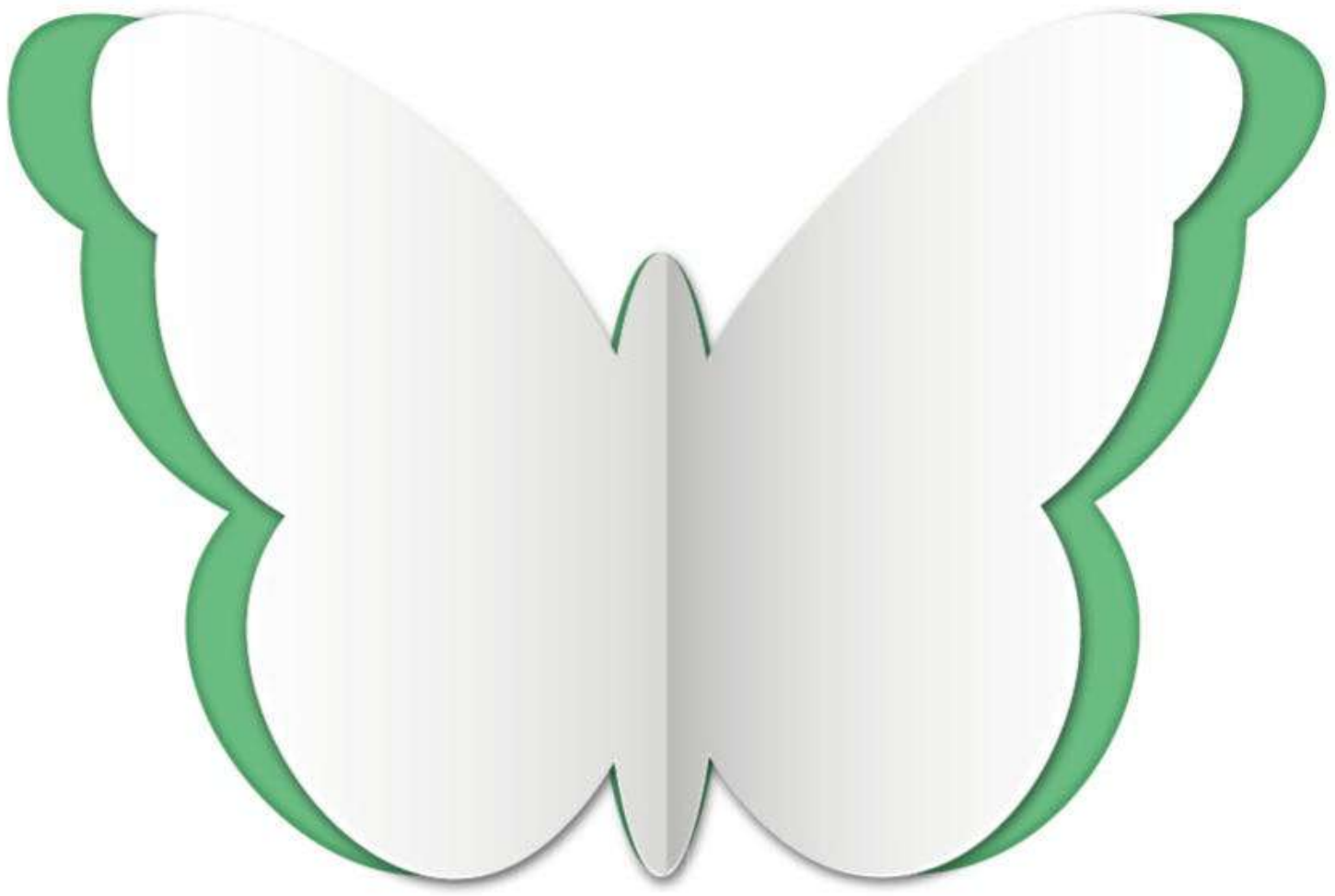
FUTURE
ISSUE 182



PAPER & BIODIVERSITY

Forests cover 31% of the world's total land area and contain most of the world's earthly biodiversity. To ensure the long-term health of forests, the European paper industry counts on sustainable forest management as a source for its main raw material.

Source: FAO and UNEP, The State of World's Forests, 2020

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Issue 182

"This ingenious system begins before your birth and continues to make changes to your body throughout your entire life"

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How hormones control your body
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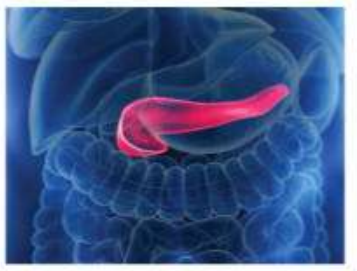

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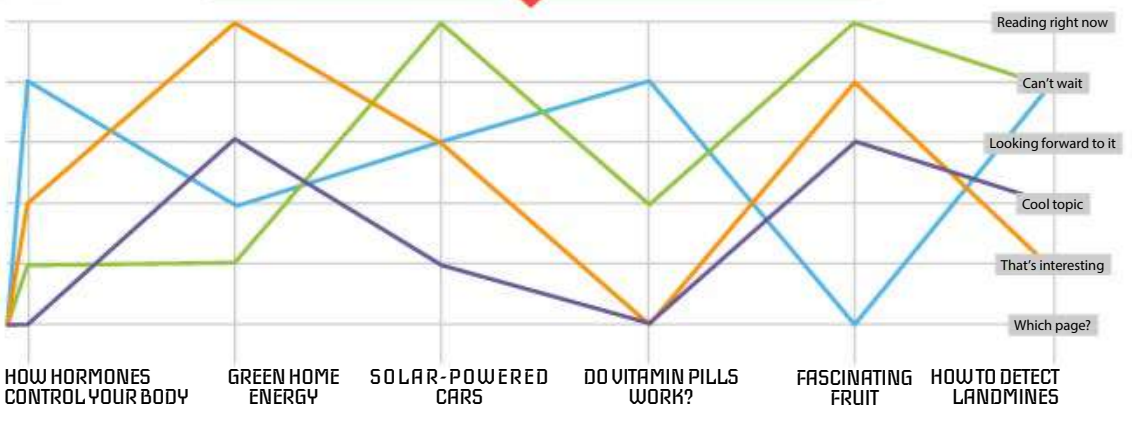
We all know that there isn't much we can do to influence the way we grow physically. Some people are just born to be bigger than others. Size is also the most recognisable form of a hormone imbalance, whether a person produces too much growth hormone and towers above even the tallest basketball players, or they don't produce enough and are much smaller than average. But a lot of us don't appreciate how much control hormones have over our energy levels, our moods and the way we think, our appetite and almost every facet of us as a person. This issue we're exploring the endocrine system, the many hormone-producing glands that help regulate our various vital bodily functions and what happens when they go wrong. Enjoy the issue!

Ben Biggs
EDITOR

WHAT WE'RE ANTICIPATING



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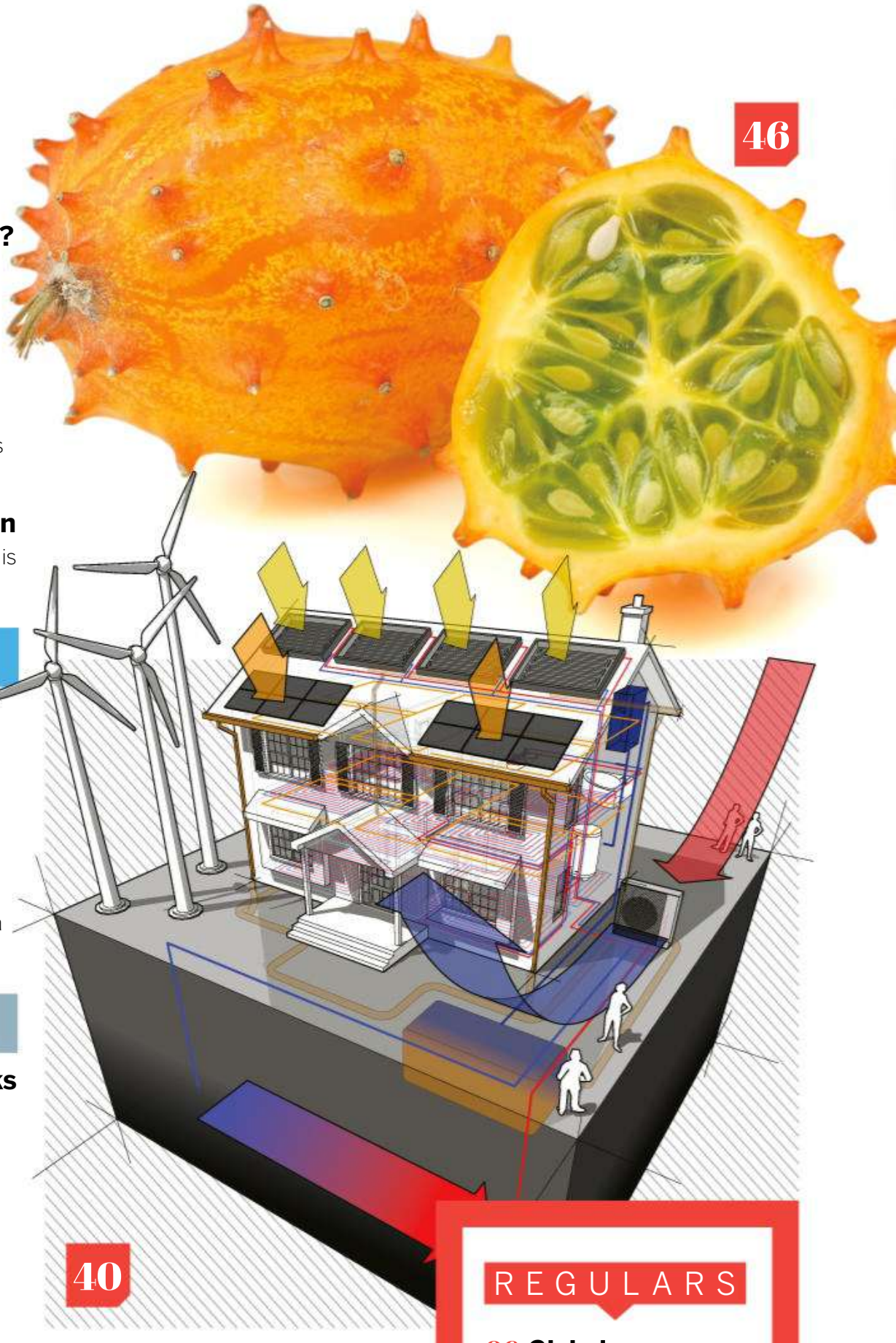

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Starfish maw

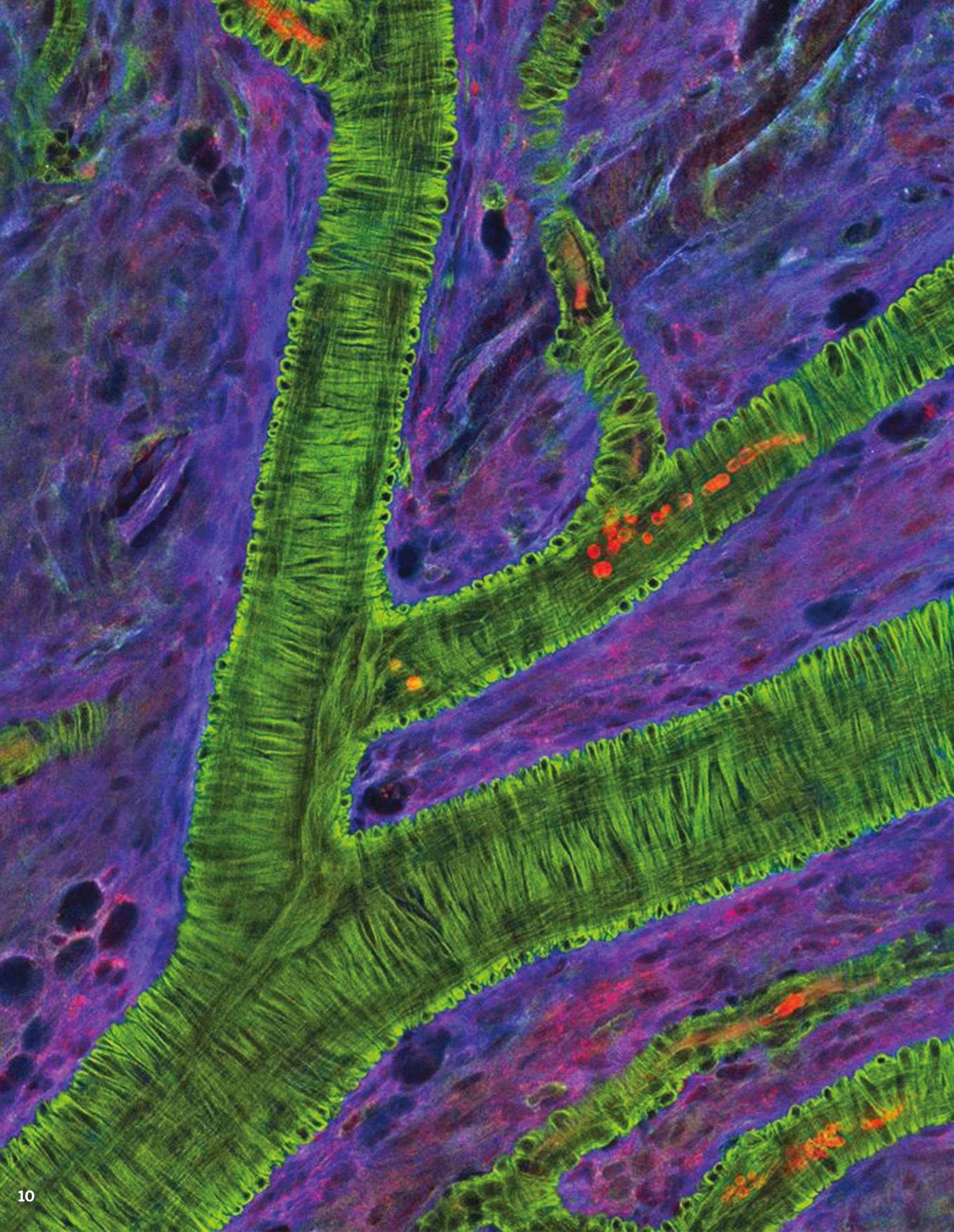
If you've ever wondered what the mouth of a starfish looks like close up, this scanning electron microscope image shows the mouth and partial arms of a serpent starfish (*Ophiura ophiura*). These peculiar starfish search the seafloor for small animals or rotting flesh called carrion. Once a meal is within their grasp, they use their arms to tear it apart and move it to the central jawed mouth.

© Alamy

Sahara from space

In 2014, astronaut Alexander Gerst snapped this striking photograph of the Sahara Desert from hundreds of miles away while aboard the International Space Station (ISS). Saharan winds throw dust and sand up into the atmosphere, as well as depositing it into the ocean. The African landscape is almost completely obscured from view because of the power of the sandstorm and bunched-up clouds.

© Alex Gerst/NASA/JSC



Behind your eyes

This is an image of the blood vessels at the back of the eye, the retina, under a microscope. The green branch-like structures indicate the size and shape of blood vessels. The stain used in this microscopy technique adheres to filaments of proteins, called actin, that wrap around each blood vessel. Although the majority of blood cells were removed to produce this image, some remain, and can be seen as red flecks.

© Alamy

The world's biggest port

Welcome to the Port of Shanghai in China. Each month, more than 2,000 ships set sail, travelling along one of the hundreds of global shipping routes the port is connected to. In 2022, the Port of Shanghai handled 47.3 million twenty-foot equivalent unit containers. The section of the Port of Shanghai seen in this image, called Yangshan Port, is the largest automated container terminal in the world.

© Getty

A new type of chemistry performed at very cold temperatures on very small particles enables quick precise reactions

CHEMISTRY

‘Quantum superchemistry’ observed for the first time ever

WORDS **STEPHANIE PAPPAS**

For the first time, researchers have observed ‘quantum superchemistry’ in the lab. Long theorised but never before seen, quantum superchemistry is a phenomenon in which atoms or molecules in the same quantum state chemically react more rapidly than atoms or molecules that are in different quantum states. A quantum state is a set of characteristics of a quantum particle, such as spin or energy level.

To observe this new super-charged chemistry, researchers had to coax not just atoms, but entire molecules into the same quantum state. When they did, however, they saw that the chemical reactions occurred collectively, rather than individually. And the more atoms were involved, meaning the greater the density of the atoms, the quicker the chemical reactions went. “What we saw lined up with the theoretical predictions,” said Cheng Chin, a professor of physics at the University of Chicago. “This has been a scientific goal for 20 years, so it’s a very exciting era.”

Researchers observed the quantum superchemistry in caesium atoms that paired up to form molecules. First, they cooled caesium gas to near absolute zero, the point at which all motion ceases. In this chilled state, they could ease each caesium atom into the same quantum state. They then altered the surrounding magnetic field to kick off the chemical bonding of the atoms. These atoms reacted more quickly together to form two-atom caesium molecules than when the researchers conducted the experiment in normal non-supercooled gas. The resulting molecules also shared the same quantum state, at least over several milliseconds, after which the atoms and molecules started to decay, no longer oscillating together. “With this technique, you can steer the molecules into an identical state,” Chin said.

The researchers found that though the end result of the reaction was a two-atom molecule, three atoms were actually involved, with a spare atom interacting with the two bonding atoms in a way that facilitated the reaction. This could be useful for applications in quantum chemistry and quantum computing, as molecules in the same quantum state share physical and chemical properties. The experiments are part of the field of ultracold chemistry, which aims to gain incredibly detailed control over chemical reactions by taking advantage of the quantum interactions that occur in these cold states. Ultracold particles could be used as qubits, or the quantum bits that carry information in quantum computing, for example.

The study used only simple molecules, so the next goal is to attempt to create quantum superchemistry with more complex molecules. “How far we can push our understanding and our knowledge of quantum engineering into more complicated molecules is a major research direction in this scientific community,” Chin said.

SPACEFLIGHT

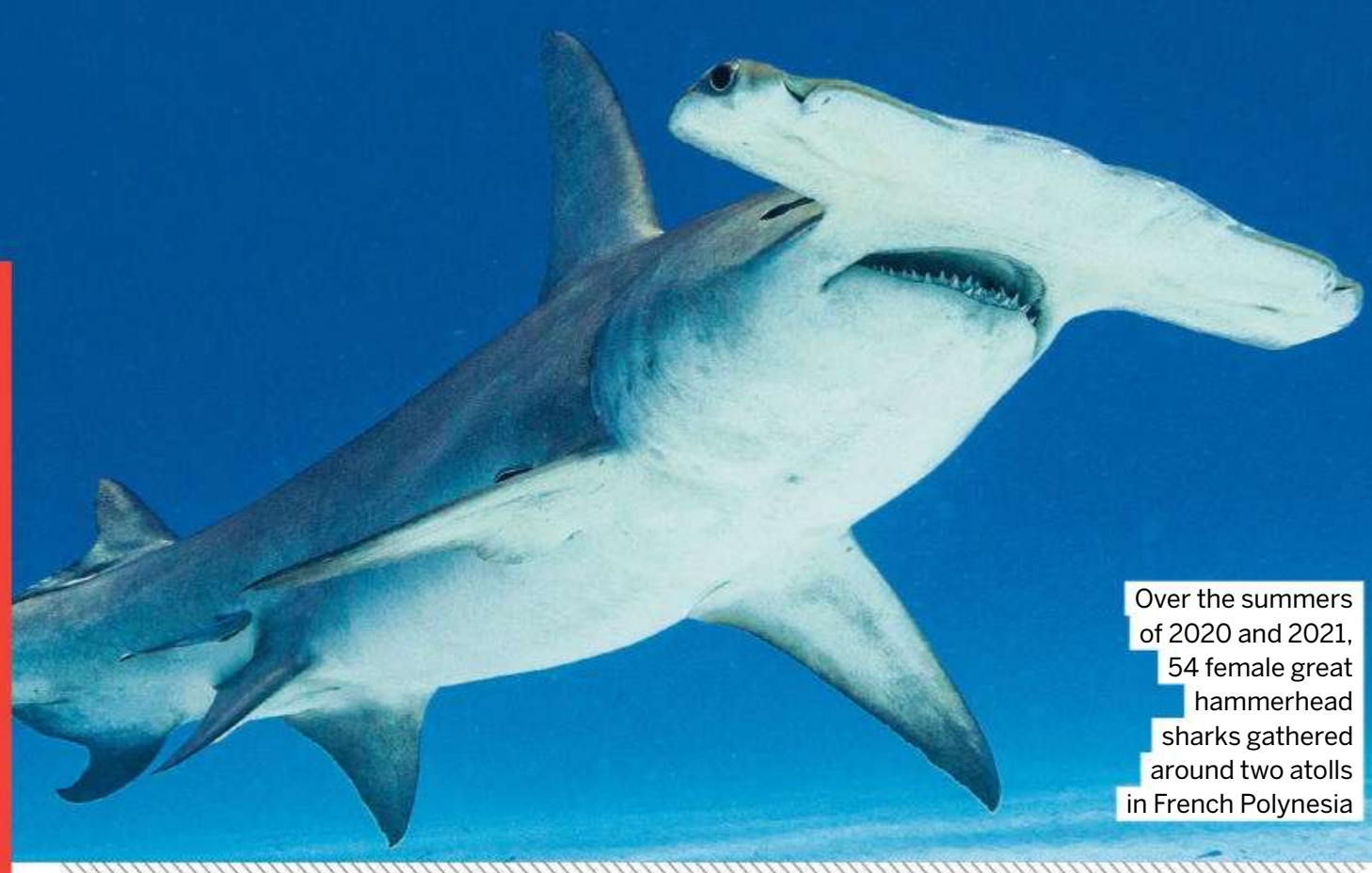
EUROPE ASSEMBLES THE HERA SPACECRAFT TO EYE THE DART ASTEROID CRASH

WORDS **ANDREW JONES**

The European Space Agency's (ESA) Hera spacecraft is now assembled ahead of its journey to analyse the asteroid smashed by NASA's DART mission. NASA's Double Asteroid Redirection Test (DART) impacted Dimorphos, the smaller companion of the asteroid Didymos, in September 2022, creating debris and altering the space rock's orbit. The ESA is now preparing its contribution to the DART international planetary defence experiment, Hera, which will follow up on the aftermath. The two modules of the spacecraft were recently mated at the facilities of technology company OHB in Bremen, Germany, in a three-hour process. "Previously we had these two modules; now you can say the spacecraft has been born," said Hera system engineer Paolo Martino. "Next we will be adding some payload units to the spacecraft's top deck, which we are receiving directly from the manufacturers once Hera moves to its next stop."

Hera will be transported to the Netherlands. There it will undergo an environmental test campaign as part of flight-readiness checks. The craft is set to launch from Cape Canaveral in October 2024 atop a SpaceX Falcon 9 rocket. Hera will reach Dimorphos in late 2026, four years after DART slammed into the asteroid moonlet.

This propulsion module was mated with Hera's core module to complete the spacecraft structure



Over the summers of 2020 and 2021, 54 female great hammerhead sharks gathered around two atolls in French Polynesia

ANIMALS

Each year, dozens of female hammerhead sharks convene under the full Moon

WORDS **SASCHA PARE**

An unusual, all-female assembly of great hammerhead sharks has been gathering in the tropical waters of French Polynesia every summer for over a decade, with numbers peaking around the full Moon. These critically endangered sharks convene between December and March around openings in two atolls, Rangiroa and Tikehau, in the Tuamotu Archipelago.

In the summers of 2020 and 2021, researchers recorded 54 female great hammerhead sharks (*Sphyrna mokarran*) and one whose sex could not be determined at the two atolls, which are nine miles apart. They noted that more than half of the sharks were seasonal residents, meaning they spent up to six days a month there for up to five months. Female sharks in the vicinity of Rangiroa mostly gathered in a spot called 'hammerhead plateau', an area 45 to 60 metres deep. "They were mainly sighted roving around the bottom of the plateau, independently from one another," researchers wrote in the new study.

Great hammerhead sharks are a solitary species, so the high number of females sighted at the same time indicates the area is an aggregation site. The sharks likely have no relationship to each other, but are drawn there by external factors that appear to be linked to the lunar cycle and the presence of ocellated eagle rays (*Aetobatus ocellatus*). The number of sharks peaked in the days shortly before and after a full Moon during both summers, perhaps because the increased moonlight enhanced their ability to hunt around the atolls at night. The sharks may also have responded to changes in Earth's geomagnetic field as the Moon waxes and wanes.

Did you know?

Great hammerhead sharks can live up to 44 years old

Large gatherings of great hammerheads in the area coincided with high numbers of ocellated eagle rays entering the lagoons to reproduce. Sharks prey on these rays, whose mating season is "a predictable event that sharks could try to intercept," the researchers wrote. Increased water temperatures may also lure sharks to the archipelago. The researchers compared their observations with long-term data collected on the atolls, which revealed that some sharks have been returning every summer for 12 years. The team identified an additional 30 male and female sharks from these records and found that males were primarily sighted from August to October, rather than during the summer.

Segregation between males and females has previously been reported for scalloped hammerheads (*Sphyrna lewini*), but not for great hammerheads. The researchers' findings suggest that males remain at a distance from the sites occupied by females during the austral summer, which could be linked to their breeding period. "Lagoons and their protected warm, shallow, coastal waters are known to serve as nursery areas for various shark species," the researchers wrote. While they couldn't confirm this in the new study, further investigation is underway to determine whether Rangiroa and Tikehau provide nursery grounds for great hammerhead sharks.

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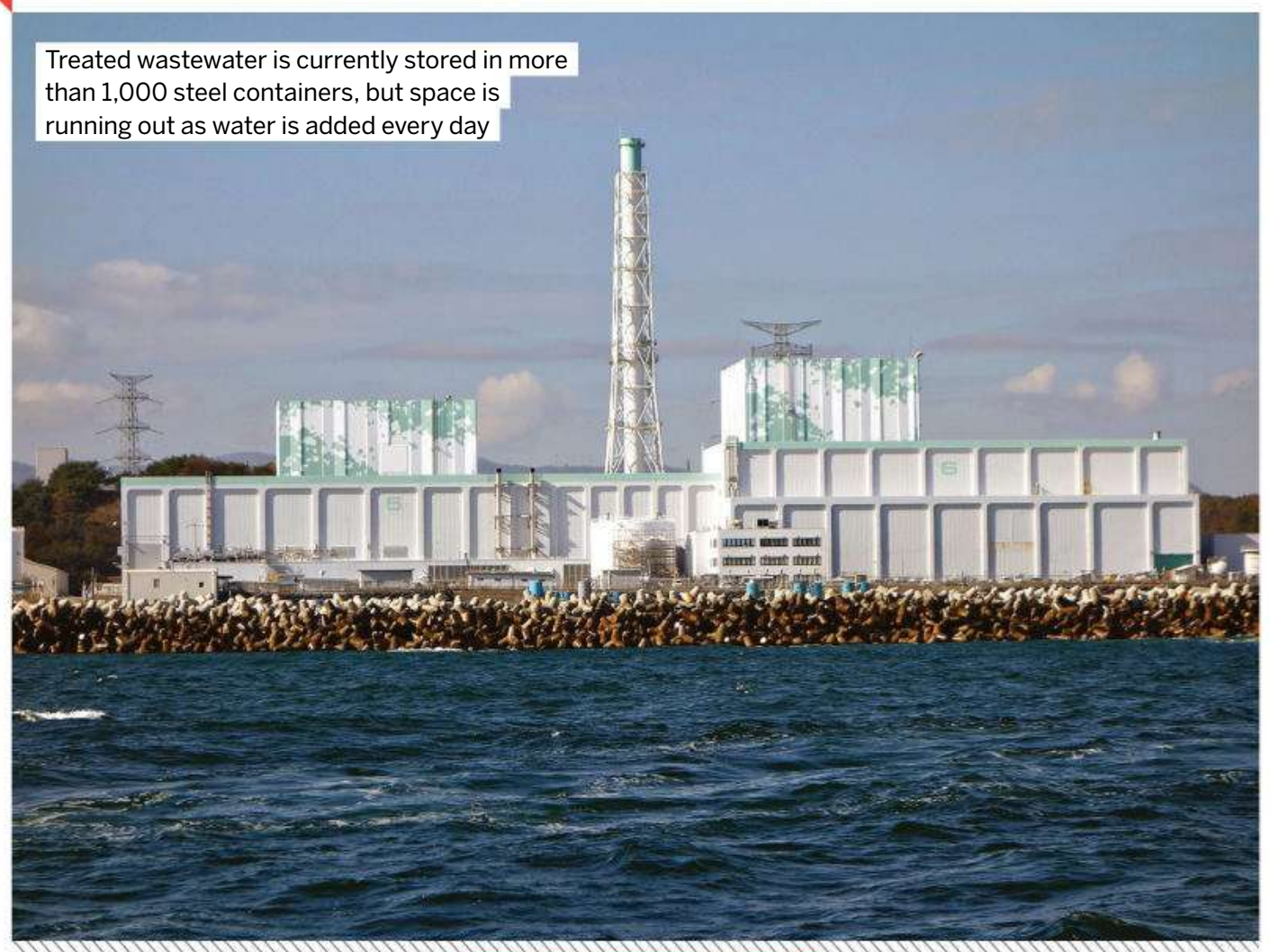
GLOBAL EYE



Treated wastewater is currently stored in more than 1,000 steel containers, but space is running out as water is added every day

PLANET EARTH

Fukushima Daiichi Nuclear Power Plant is pumping wastewater into the ocean

WORDS SASCHA PARE

Japan has begun discharging wastewater from the Fukushima Daiichi Nuclear Power Plant into the Pacific Ocean, the first of four releases planned before March 2024. The Tokyo Electric Power Company (TEPCO) activated the seawater transfer pumps on 24 August. Experts estimate it will take 17 days to complete the release and discharge the roughly 7,800 cubic metres of water into the sea.

The International Atomic Energy Agency (IAEA), the UN's atomic watchdog, has approved the release and found it complies with international safety standards. "The controlled, gradual discharges of the treated water to the sea, as currently planned and assessed by TEPCO, would have a negligible radiological impact on people and the environment," Rafael Mariano Grossi, director-general of the IAEA, wrote in a report.

Roughly 1.34 million tonnes of water – equivalent to 540 Olympic swimming pools – that was used to cool the reactors, or seeped in through the ground or rain, is stored in 1,000 steel containers at the seaside Fukushima Daiichi Nuclear Power Plant. The site is now close to full capacity. Japan announced in 2021 that it would release millions of tonnes of nuclear wastewater into the sea via a pipe stretching 0.6 miles out from the coast. The water was treated with a special filtering system that removes all the radioactive elements except tritium, an isotope of hydrogen that's very difficult to eliminate. Tritium has a half-life of 12.33 years, and as it decays it converts into helium.

Nuclear power facilities regularly release tritium into waterways across the world, Tony Hooker, an associate professor at the University of Adelaide in Australia who specialises in radiation protection, said. "For decades [there have been] no evidential detrimental environmental or health effects," he said. TEPCO said it has diluted the wastewater to reduce remaining radioactivity levels to 1,500 becquerels per litre, which is well below Japan's national safety standard of 60,000 becquerels. The World Health Organization (WHO) limits radioactivity for drinking water to 10,000 becquerels per litre.

Plant operators have yet to clear the remaining debris and nuclear fuel in three reactors that went into meltdown after the massive earthquake and tsunami that decimated the Fukushima Daiichi Nuclear Power Plant in March 2011.

HISTORY

AN EIGHT-YEAR-OLD BOY UNEARTHED A ROMAN-ERA SILVER COIN IN THE SCHOOL SANDBOX

WORDS MEGAN SHERSBY

An eight-year-old boy playing in a sandbox at his primary school in Germany unearthed an 1,800-year-old silver coin minted during the Roman Empire's Pax Romana. Overwhelmed with excitement at finding buried treasure, the boy, identified only by his first name, Bjarne, rushed home to show the coin to his family in Bremen, a city in northern Germany, upon finding it in August 2022. After his parents contacted authorities, archaeologists confirmed that the coin was a Roman denarius minted during the reign of Emperor Marcus Aurelius Antoninus, who held the throne from 161 to 180 CE.

The heavily worn coin, which weighs 2.4 grams, was minted during a "time of coin deterioration," said state archeologist Uta Halle, when the Roman Empire decreased the silver content in its currency as a direct result of inflation. Halle called the find "something very special," since it's one of the few times a denarius has been discovered in Bremen. While this region of Germany was never under Roman rule, it was inhabited by the Chauci, an ancient Germanic tribe that often traded with ancient Romans. This could explain how the coin wound up buried in German soil. Unfortunately, Bjarne won't be able to keep the coin, as finds like this one belong to the state.

The heavily worn coin was minted 1,800 years ago

SPACE

Black holes keep ‘burping up’ stars they destroyed years earlier

WORDS ROBERT LEA

Up to half of the black holes that devour stars ‘burp up’ their stellar remains years later. Astronomers made the discovery after spending years watching black holes involved in tidal disruption events (TDEs). TDEs occur when stars venture too close to black holes. The immense gravity of these cosmic monsters exerts incredible tidal forces that stretch and squeeze the stars in a process called spaghettification. The unfortunate stars involved in TDEs are ripped apart or ‘unravelled’ in a matter of hours, signalled by a powerful flash of electromagnetic radiation in visible light.

Some of the stellar material of the destroyed star is flung away from the black hole, while the rest forms a thin frisbee-like structure around it called an accretion disc, which gradually feeds that material to the black hole. In its early days the accretion disc is unstable, and matter sloshes around and smashes into itself, causing outflows detectable by their radio waves. But astronomers traditionally only look at these star-eating black holes for a few months following the TDEs.

In a new study, astronomers watched black holes involved in TDEs for hundreds of days, finding that in up to 50 per cent of the cases, the black holes ‘burped back’ stellar matter years after. “If you look years later, a very large fraction of these black holes that don’t have radio emission at these early times will actually suddenly ‘turn on’ in radio waves,” said Yvette Cendes, a research associate at the Harvard-Smithsonian Center for Astrophysics.

The re-emission of this material for 10 of the 24 black holes happened between two and six years after the star-destroying events. Cendes and the team don’t know what’s causing black holes to ‘switch on’ after many years, but whatever it is definitely doesn’t come from inside the black holes.

Did you know?

The mass of the largest known black hole is equal to 30 billion Suns

Black holes are marked by an event horizon, the point at which gravity is so strong that not even light can escape. “Black holes are very extreme gravitational environments even before you pass that event horizon, and that’s what’s really driving this,” Cendes said. “We don’t fully understand if the material observed in radio waves is coming from the accretion disc or if it is being stored somewhere closer to the black hole. Black holes are definitely messy eaters, though.”

Part of the mystery stems from computer models that simulate TDEs, which typically terminate just weeks after the destruction of the star. The new research suggests the models need to be updated to capture some of the black holes’ most unexpected behaviour. For instance, in two cases the radio waves emitted by black holes peaked, faded and then peaked again. “There was a second peak – the two black holes re-brightened – and that’s completely new and unexpected,” Cendes said. “People were thinking that you’d have one outflow, and then it’s kind of done. So this observation means these black holes can ‘turn on’ and then ‘turn on’ again.” Cendes said that the team will keep monitoring all of the TDE-causing black holes, especially as some of them are still getting brighter.

An illustration showing a tidal disruption event – a black hole ripping apart a star and devouring it

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SPACE

THE INTERNATIONAL SPACE STATION FIRED ITS THRUSTERS TO AVOID ONCOMING SPACE JUNK

WORDS **ELIZABETH HOWELL**

Space debris flying towards the International Space Station (ISS) forced an evasive manoeuvre on 24 August. A Russian module on the ISS turned on around 15:00 GMT to move the orbiting complex away from space junk. "On Thursday, the International Space Station's Zvezda service module engines were fired for 21.5 seconds ... to manoeuvre the complex away from the predicted track of an orbital debris fragment," NASA said in an official statement.

The space station moved its orbit down towards our planet by about 500 metres. The average altitude of the ISS above Earth is roughly 250 miles. The orbit adjustment will not have any impact on operations. Course corrections by the ISS have happened more than 30 times since 1999, and the need is accelerating as more satellites and space junk accumulate in orbit. It's unclear how close the debris passed by the station this time, or whether it was a natural or artificial piece of debris. In general, however, such flybys happen from relatively afar.

NASA's guidelines monitor the ISS for any debris coming within a pizza box-area shape of space around the station's orbit, which is roughly 2.5 by 30 by 30 miles, with the ISS at the centre. Tracking comes via the US military, which can follow flying pieces as small as five centimetres in diameter.

The International Space Station in orbit above Earth

Did you know?

The ISS weighs around 420,000 kilograms

PHYSICS

A 'doubly magic' form of oxygen may challenge the laws of physics

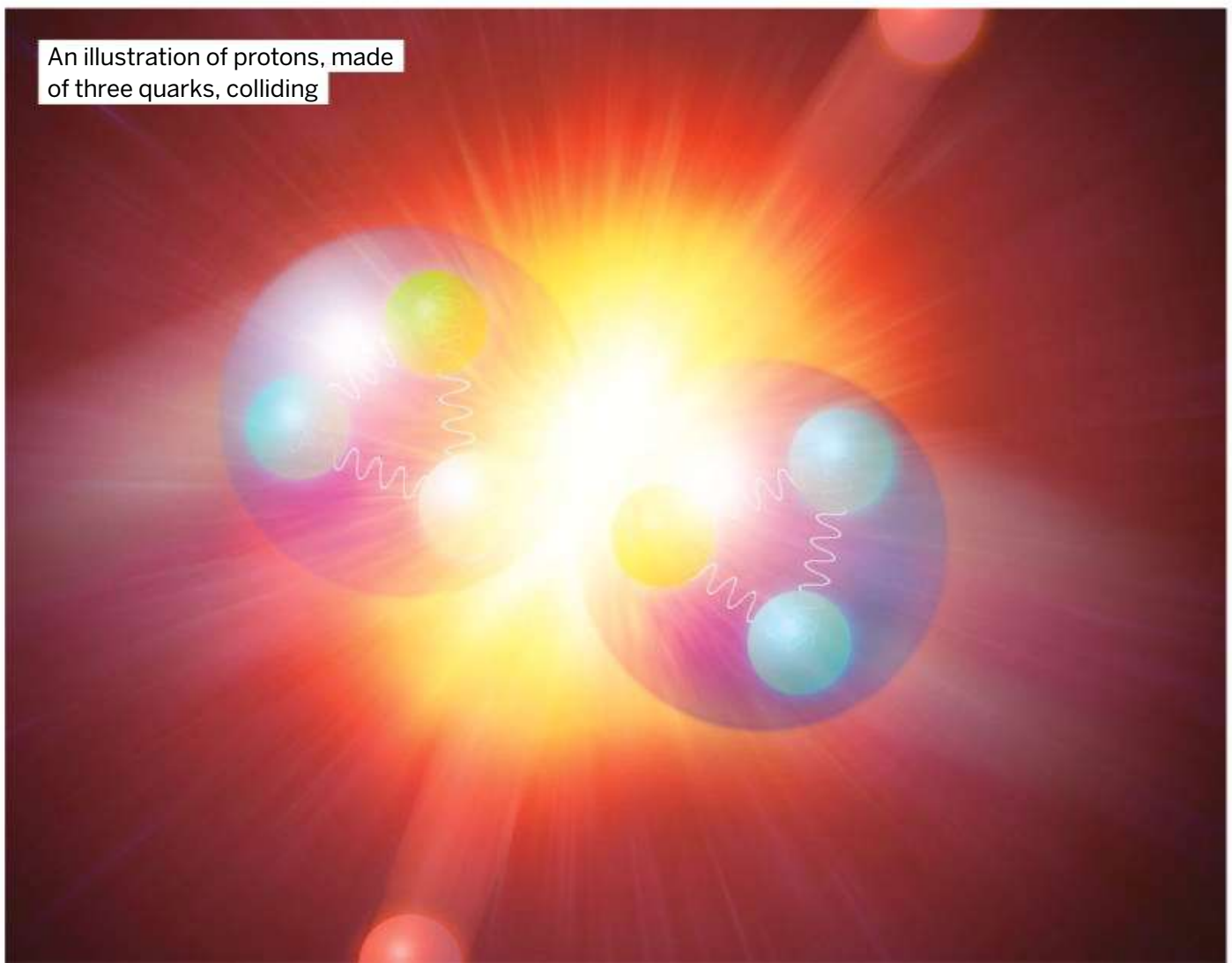
WORDS **KILEY PRICE**

For the first time, scientists have created oxygen-28, a rare oxygen isotope that has 12 more neutrons than oxygen-16, the most common form of oxygen on the planet. This new 'heavy' isotope has the highest number of neutrons ever seen in an oxygen atom and was expected to be ultrastable. Instead it degraded quickly, a finding that challenges our understanding of the strong force, which binds the fundamental particles of matter, such as protons and neutrons, to form larger particles in an atom's nucleus. "It opens a very big fundamental question about nature's strongest interaction, the nuclear strong force," said Rituparna Kanungo, a physicist at Saint Mary's University in Canada.

To create oxygen-28, a team led by researchers at the Tokyo Institute of Technology blasted a beam of fluorine-29, an isotope that has nine protons, at a liquid-hydrogen target at the RIKEN RI Beam Factory in Wakō, Japan. Upon impact, both the hydrogen and the fluorine-29 lost a proton, which created an entirely new molecule of oxygen-28. Under the Standard Model, the leading theory of particle physics, particles should be stable if the shells in an atom's nucleus are filled with certain numbers of protons and neutrons, known as 'magic' numbers. Oxygen-28 contains 20 neutrons and 8 protons, both of which are magic numbers, suggesting that the molecule should have been supremely stable, or 'doubly magic'. But that was not the case.

During the experiment, the oxygen-28 molecule decayed within a zeptosecond, or a trillionth of a billionth of a second. In fact, its presence was only confirmed by the products it left behind when it decayed: oxygen-24 and four neutrons. Though the experiment has not yet been replicated, the findings of this study suggest that the current list of magic numbers may not tell the full story of whether molecules are stable. In a separate case in 2009, scientists showed that an oxygen-24 isotope behaved as though it were doubly magic, even though it did not have a magic number of protons and neutrons.

The new study could pave the way for future research that may provide more clues about the mysterious forces glueing particles together in an atom's nucleus. "I think the results of the experiments demonstrate the importance of studying these exotic nuclei along and beyond the limit of existence," said Michael Thoennessen, a professor of physics at Michigan State University. "We still do not fully know what binds neutrons and protons together to form nuclei. Exploring these extremes tests the foundations of the nuclear models."



An illustration of protons, made of three quarks, colliding

An analysis of buffalo mozzarella from two Italian dairies has revealed which bacteria define this beloved cheese

HEALTH

Scientists identify the microbes that make buffalo mozzarella so tasty

WORDS **EMILY COOKE**

Bubbling blobs of buffalo mozzarella seen steaming atop a pizza as it comes out of the oven – it's a scene tantalising enough to make almost anyone's mouth water. But what makes this creamy white cheese so delicious? After studying samples of buffalo mozzarella from two dairies in Italy's Campania region, where the beloved water buffalo-milk cheese originated, scientists revealed that despite subtle variations in how the cheeses were made, they were dominated by the same two groups of microbes: a genus of spherical, chain-forming bacteria known as *Streptococcus* and a genus of rod-shaped bacteria called *Lactobacillus*. And within these broad groups of bacteria, some species were specific to each dairy's cheese.

In a recent study, researchers have found that the cheeses' processing and raw ingredients give them their distinct microbial profiles, and this likely helps produce their world-renowned taste. "This study sheds light on the intricate interactions of microorganisms throughout the manufacturing process and fosters a deeper understanding of the craftsmanship behind this esteemed Italian cheese," said Alessia Levante, an industrial microbiology researcher at the University of Parma in Italy.

Levante's team looked at two dairies that make Mozzarella di Bufala Campana PDO, a cheese that must be produced in the Campania region using a specific recipe to earn its 'protected designation of origin' label that has been safeguarded by the European Union for 30 years. To make the coveted cheese, cheese-makers heat raw or pasteurised water buffalo milk to between 33 and 39 degrees Celsius. Then they add enzymes from the stomach lining of a calf, known as rennet, which breaks the milk into curds – the clumped milk solids – and whey, the leftover liquid. They also add a crucial collection of bacteria, called a natural whey starter, that helps increase the acidity of the resulting curds.

After coagulating into curds, the cheese can then be moved to boiling water to melt together and be made stretchable. The cheese-maker then moulds the cheese into shape, places it in cold water to harden and finally puts it in a brine before packaging. The first dairy in the study was smaller and used more traditional processing techniques, whereas the other larger dairy used more modern technology. The team took 19 samples of cheese in total and used genetic sequencing to investigate which bacteria were present at each stage of the manufacturing process.

The team found that the pasteurised milk used by the modern dairy added fewer microbes overall and fewer species of bacteria to the production process than the milk that had been 'thermised' by the traditional dairy. Both thermisation and pasteurisation involve using heat to kill harmful bacteria in milk, but the former uses lower temperatures of around 57 to 68 degrees Celsius, compared with 72 degrees Celsius for the latter. Both dairies' brines, however, were equally rich in microbial species, but not all these species ultimately jumped from the brine to the cheese itself.

Both dairies' natural whey starters were dominated by *Lactobacillus* and *Streptococcus* bacteria, and during curdling these genera were dominant in the cheeses. After curdling, the amount of *Lactobacillus* increased and *Streptococcus* decreased in both dairies' samples, likely because the bacteria were no longer exposed to the heat stress that accompanied the stretching process.

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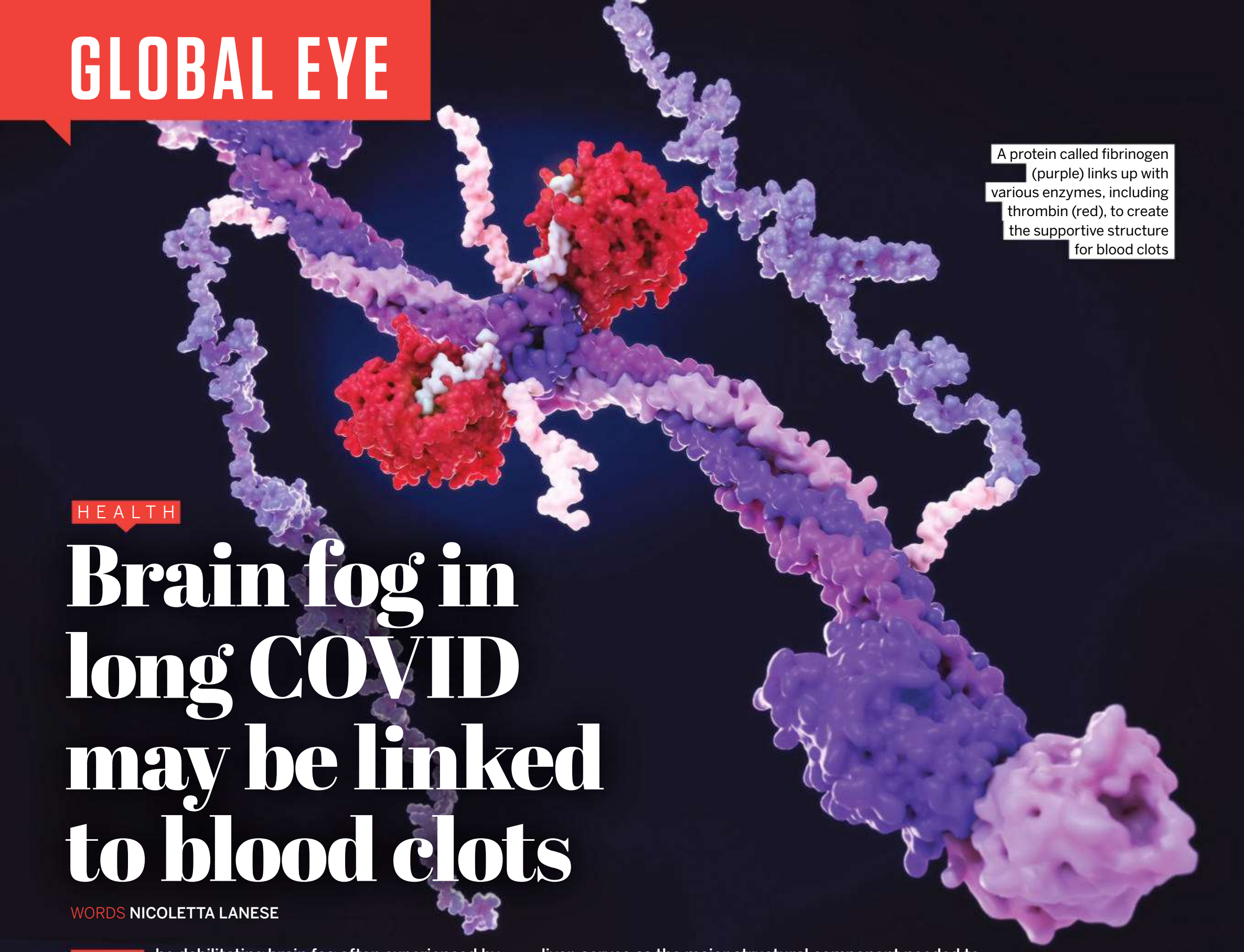

A protein called fibrinogen (purple) links up with various enzymes, including thrombin (red), to create the supportive structure for blood clots

HEALTH

Brain fog in long COVID may be linked to blood clots

WORDS NICOLETTA LANESE

The debilitating brain fog often experienced by people with long COVID may stem from blood clots. Long COVID describes symptoms that linger for weeks to years after a COVID-19 infection. Some people with the condition experience problems with blood flow and lung capacity, which have been linked to tiny, abnormal blood clots. Researchers have suggested that clots may also drive neurological symptoms of long COVID, like brain fog, which can disrupt people's ability to focus, remember and execute tasks.

A recent study backs this idea linking blood clots to brain fog. However, it doesn't fully connect the dots to show how the clots might actually damage nerves or the brain to trigger brain fog. The new research used data from nearly 1,840 adults who were hospitalised with COVID-19 in the UK in 2020 and 2021. This narrowed the study's focus to unvaccinated patients who'd developed severe infections, so it's unclear how well the results extend to vaccinated people and those who develop long COVID after mild or asymptomatic infections. As part of the post-hospitalisation COVID-19 study, the participants gave blood samples at the time of hospitalisation, and then 6 and 12 months later took cognitive tests and filled out questionnaires.

Two proteins involved in blood clotting, called fibrinogen and D-dimer, jumped out as key predictors of people's cognitive problems down the line. Fibrinogen, made by the liver, serves as the major structural component needed to form a blood clot, and D-dimer is a protein fragment released when blood clots break down. Compared with those who had less fibrinogen, hospitalised patients with the highest levels of fibrinogen scored worse on memory and attention tests and rated their cognition as worse on surveys. Similarly, people with high D-dimer levels later rated their cognition more poorly on subjective surveys than people with low D-dimer did. The high-D-dimer group was also more likely to report problems with their ability to work 6 and 12 months out from hospitalisation.

The two blood-clotting proteins have previously been linked to severe COVID-19, and separately, fibrinogen alone has been associated with cognitive issues and dementia. At this point, it's unknown how the proteins might be driving brain fog in long COVID. Fibrinogen-related blood clots may be derailing blood flow to the brain, or perhaps directly interacting with nerve cells. D-dimer may be more linked to clots in the lungs and breathing issues, which were commonly reported in the high-D-dimer group. "Future research should look at whether treatment targeting blood clotting, for example blood thinners, might help people with these symptoms," Dr Aravinthan Varatharaj, a clinical lecturer in neurology at the University of Southampton, said. This use for blood thinners would have to be rigorously tested in trials.

Hogfish are the chameleons of the ocean, able to change skin colour

ANIMALS

Colour-changing hogfish use their skin to 'see' themselves

WORDS JENNIFER NALEWICKI

Hogfish are the chameleons of the Atlantic Ocean, seamlessly changing their skin colour depending on their environment. As if those morphing skills weren't impressive enough, these reef dwellers can also 'see' with their skin with the help of special light-sensing cells, even after they die. Lorian Schweikert, an assistant professor in the Department of Biology and Marine Biology at the University of North Carolina Wilmington, witnessed this colour-shifting phenomenon firsthand during a fishing expedition in Florida, when she watched a hogfish (*Lachnolaimus maximus*) she caught change its skin colour to match the patterned white deck of the boat. "They appear to be watching their own colour change," said Schweikert.

Hogfish are typically found in coral reefs and are master magicians; as protogynous hermaphrodites, they can switch their sex from female at birth to male as adults. Now Schweikert and her team think they've discovered how this colour-shifting magic works by identifying specialised light-sensing cells located beneath a layer of colour-changing cells in hogfish skin. This system enables them to watch their skin change colour and adjust it to match their surroundings. This finding comes on the heels of a 2018 study in which Schweikert and her colleagues identified light-detecting proteins in hogfish skin. Called SWS1 opsins, these proteins are particularly sensitive to blue light. Interestingly, they're also found in human retinae. By using a biochemical technique known as immunolabeling, the research team pinpointed the proteins' exact locations in hogfish skin samples.

In the new study, the researchers likened the light-sensitive opsins to Polaroid film, since it captures changes in the light that hogfish can filter through their cells. "The animals can literally take a photo of their own skin from the inside," said Sönke Johnsen, a biology professor at Duke University. "In a way they can tell the animal what its skin looks like, since it can't really bend over to look." However, the researchers were quick to emphasise that hogfish can't actually see with their skin as they do with their eyes, because eyes do more than detect light – they also receive information from the brain to unveil images. "Just to be clear, we're not arguing that hogfish skin functions like an eye," Schweikert said. "We don't have any evidence to suggest that's what's happening in their skin."

HISTORY

Human 'effigies' unearthed at an Aztec temple were likely looted in battle

WORDS JENNIFER NALEWICKI

Archaeologists in Mexico City have unearthed a collection of stone figurines depicting humans – carvings that the Aztecs once likely used as offerings. The 15 objects were discovered tucked inside a stone chest buried on the former site of the Templo Mayor, which once served as the temple complex of Tenochtitlán, the capital of the Aztec Empire. Spanish forces destroyed the temple in 1521, and the site is now home to the Mexico City Metropolitan Cathedral.

14 of the artefacts portray men, while the smallest of the group features a woman. All of the figurines are in the Mezcala style, related to an early Mesoamerican culture that once existed in Guerrero, a state in southern Mexico that was known for creating objects depicting humans. Researchers think the Aztecs valued Mezcala objects and may have looted the sculptures in battle. "This means that when they subdued those peoples, the figurines were already true relics, some of them more than 1,000 years old," said archaeologist Leonardo López Luján. "Presumably they served as cult effigies, which they appropriated as booty of war."

Did you know?

The Templo Mayor was around 30 metres tall

The 15 stone figurines depict 14 men and a woman

© Getty / Templo Mayor Project

WISH LIST

The latest SPACE gadgets

NASA APOLLO 15 AMERICAN MOONPHASE WATCH

$375 (APPROX. £300) WWW.XERIC.COM

The NASA Apollo 15 American Moonphase watch is a stunning celebration of the fourth manned mission to the Moon, Apollo 15. Encompassing the dial of the watch is a grille that mimics the conical shape and crew access hatches of the Command Module that carried the Apollo 15 astronauts through space.

Several details of this watch, including the lunar watch hands, are coated in a Super-LumiNova luminous material that glows brightly at night after being charged by ultraviolet light during the day. The curved sapphire crystal glass is scratch-resistant and comes with an anti-reflective coating to reduce glare. It's a beautiful timepiece that includes a lunar dial to track the phases of the Moon as it goes through its 29.5-day cycle.

ASTRO FI 102 MAKSUTOV-CASSEGRAIN TELESCOPE

£439 / $529.95

WWW.CELESTRON.COM

Great for beginners, the Astro Fi 102 is a compact telescope that lets you study celestial objects, including the rings of Saturn and the Great Red Spot on Jupiter, with ease. The telescope's simple set-up takes only a few minutes to complete, and thanks to integrated WiFi and the Celestron SkyPortal app, it can be completely remote-controlled. The built-in 'SkyAlign' technology uses any three bright objects in the sky to calculate its position. It can then generate a tour of the night sky based on your exact location for the best chance of seeing viewable celestial objects. The Astro Fi 102 also comes with a handy lens cap that doubles as a smartphone adapter. Simply place any smartphone device into the adapter and you can snap shots of the stars and beyond, as well as terrestrial targets such as birds and other wildlife.

ORZORZ STAR PROJECTOR HOME PLANETARIUM

£102.33 / $128 WWW.ORZORZVIP.COM

Gaze into the Solar System and beyond using the high-precision lens of the Orzorz home planetarium. The silent wave motor rotates a starry sky and celestial objects around your ceiling or walls, transporting you out into space from the comfort of your bed. The projector comes with a three-mode timer, which is great if you intend to drift off while watching the stars. As well as projecting an impressive starry sky, this gadget comes with five different slides, including the Milky Way, the Moon, Earth, the Pillars of Creation and the nebula NGC 2359. You can also explore more of the cosmos by purchasing additional slides, which include a whole host of nebulae and astronomical anomalies, such as the Butterfly Nebula, Bubble Nebula, black holes and spiral galaxies.

ORBITING SOLAR SYSTEM

£30 / $29.95
WWW.THAMESANDKOSMOS.CO.UK

Bring the Solar System into your living room with this fun, build-your-own kit by Thames and Kosmos. This mechanical model comes with each of the eight planets and the Sun. When assembled, it forms a wind-up simulation of motion within the Solar System. Setting up the model is simple and straightforward. The kit comes with a colourful step-by-step illustrated guide for children aged six and above to follow. All the components are also assembled using snap-together plastic parts, which will not only teach your little ones about the science of the Solar System and how fast planets orbit the Sun, but will introduce them into how gears and wind-up mechanisms work.

QUEST 2 AND SPACE EXPLORERS

FROM £299.99 / $299.99 **WWW.META.COM**

If you've ever wondered what it would be like to venture beyond the pull of Earth's gravity and into unknown space, with the help of virtual reality, you can find out. The Quest 2 is well known as an impressive all-in-one VR device that lets you step into countless games and experiences with unparalleled immersion. Now you can accompany astronauts as they traverse space and live among the stars in *Space Explorers: the ISS Experience*.

This virtual experience is a four-part immersive series, the largest production ever filmed in space, and follows the lives of astronauts aboard the International Space Station. There is also an extended spacewalkers version of the experience that lets you follow the astronauts beyond the walls of the ISS.

EVSCOPE 2

£3,999 / $4,899 **WWW.UNISTELLAR.COM**

For serious astronomers, the eVscope 2 is arguably one of the most high-tech telescopes you can buy. Unlike most telescopes, the eVscope 2 doesn't just let you look out to the stars – it transforms the view of celestial objects with impressive clarity and vivid colour. Using Unistellar 'Enhanced Vision' technology, the eVscope 2 amplifies incoming light and continuously processes short exposures of objects to generate a view of the night sky you've not seen through a telescope before. Unistellar also strips away light pollution from clouded views, allowing you to take clear and precise photographs regardless of the brightness outside. Using the accompanying app, you can set the eVscope 2 to autonomously locate and target certain celestial objects and track them as they pass over the sky. Without the need for complex set-up or mind-boggling settings, this telescope is a game changer when it comes to accessibility.

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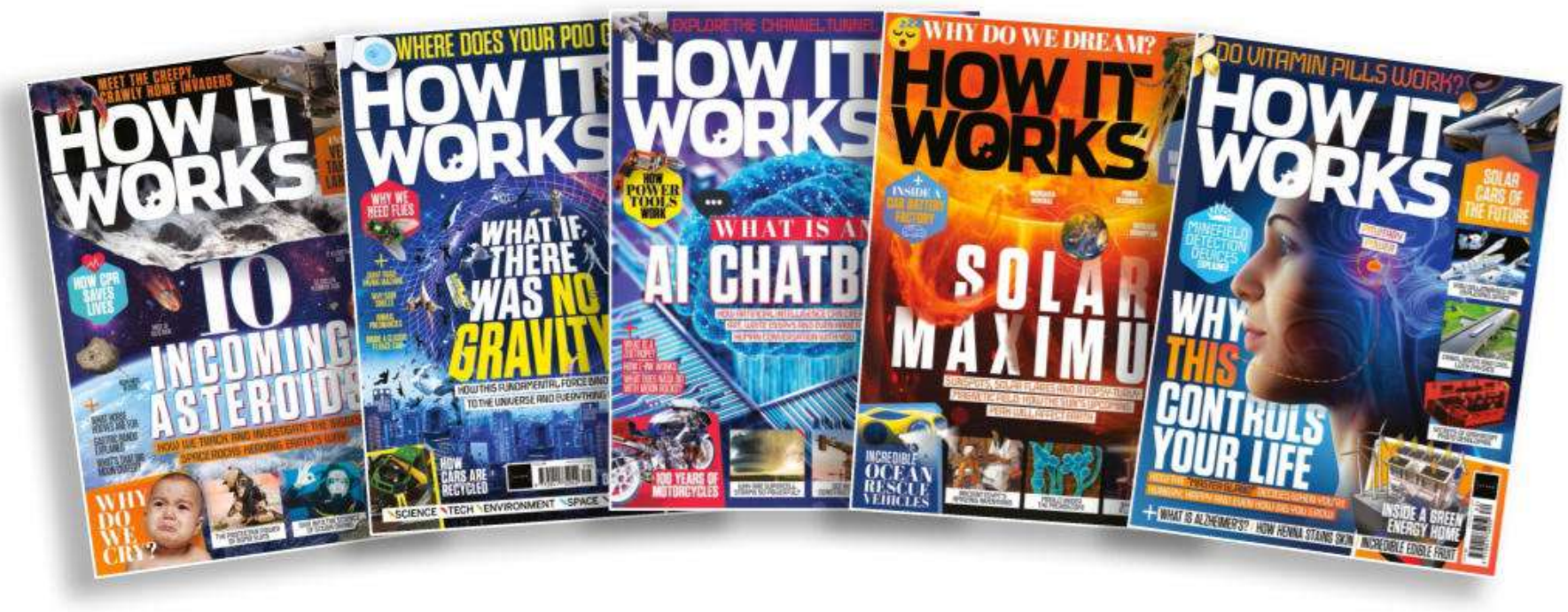

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SPECIAL

HOW HORMONES CONTROL YOUR BODY

Just as the nervous system sends information around the body via electrical impulses, the endocrine system provides another messaging service that has complete control of your body

WORDS JOANNA ELPHICK

DID YOU KNOW? Hormones aren't just made in the glands. They can be made in your fat cells, intestines and even your bones

If you've ever wondered why you never seem to get any taller while your friends are regularly growing out of their clothes, why your skin always breaks out in spots when you want to look your best and why you're always hungry no matter how much you eat, you need look no further than your hormones. But what exactly are hormones, and why do they seem intent on interfering in your life?

In simple terms, hormones are chemical molecules that act like an internal postal service. These specialised proteins carry vital messages around the body via the bloodstream – thanks to the circulatory system and a strong, beating heart – to their target cells, where they give out clear instructions. Different types of hormones will give instructions to entirely different organs and tissues within the body. This ingenious system begins before your birth and continues to make appropriate changes to your body throughout your entire life, allowing you to develop, grow, thrive and survive.

The endocrine system plays an important role in the transition from foetus to independent newborn baby. Endocrine cells have started to disperse within a few weeks of gestation, and by 13 weeks have developed a hypothalamus and a pituitary gland. The foetus takes hormones from the parent and the placenta acts as a temporary endocrine organ, sharing nutrients and messages between the two. This is expelled as the baby is pushed out. The hormones help the foetus to develop and grow in utero, giving it the best chance to survive the birthing process. As soon as the baby is born, the endocrine system controls every aspect of its life, from growth and strength to temperature and mood. However, it's when reaching puberty – usually around the≈age of 12 – that most people become aware of the importance of hormones.

It's during puberty that our bodies develop into their peak physical state and complete sexual maturity. The endocrine system instigates some dramatic bodily changes that can be very confusing and frightening for any

Many women overcome menopausal side effects by undertaking hormone replacement therapy

© Getty

unprepared teenager. As adolescence begins, the hypothalamus and pituitary gland stimulate the gonads (ovaries or testes) to produce a variety of hormones that prompt new sexual characteristics. Oestrogen and progesterone increase in girls, causing the breasts to enlarge and the menstrual cycle to begin. Meanwhile, an increase in testosterone in boys initiates a deepening of the voice, enlargement of the sexual organs and an increase in facial hair. Temperament also alters, and often not for the better. In medieval times, before there was any understanding of hormonal flux, angelic children were sometimes thought to have been possessed by the devil when they reached adolescence.

But any system can malfunction, and the endocrine system is no different. An imbalance of hormones in a young child or adolescent can bring about a multitude of disorders. Precocious puberty occurs when a child begins the transition into sexual maturity at a very early age. The hypothalamus sends signals to release sexual hormones too soon, causing little girls to start their periods before the age of eight. This can sometimes be brought about by a tumour growing on one of the key endocrine glands. Meanwhile, a lack of the growth hormone can lead to dwarfism, and a deficiency in the hormone insulin can lead to childhood diabetes. It's vitally important that parents maintain a watchful eye over their children to ensure that any endocrine issues are dealt with swiftly, since early treatment of a hormonal imbalance can prevent long-term health problems.

Did you know?

Vitamin D is a vitamin, but it's a hormone, too

The endocrine system plays a vital role in adulthood, too. Hormones such as insulin and glucagon support the regulation of metabolic health, since they balance blood sugar levels. As our lives become more complicated with financial commitments and employment obligations, adults need to be capable of remaining calm under pressure in order to stay healthy. The adrenal glands release cortisol and adrenaline to combat spiking stress levels and maintain stable blood pressure. The T3 hormone released from the thyroid gland works alongside calcitonin to maintain healthy strong bones and growth.

A crucial role for the endocrine system in an adult's life concerns reproductive hormones. Oestrogen and progesterone, starting in puberty, continue to be extraordinarily important, as they not only

Hashimoto's thyroiditis occurs when antibodies attack the thyroid gland, causing an unhealthy hormone imbalance

Thanks to an excess of growth hormone, Robert Wadlow reached a height of 271.8 metres

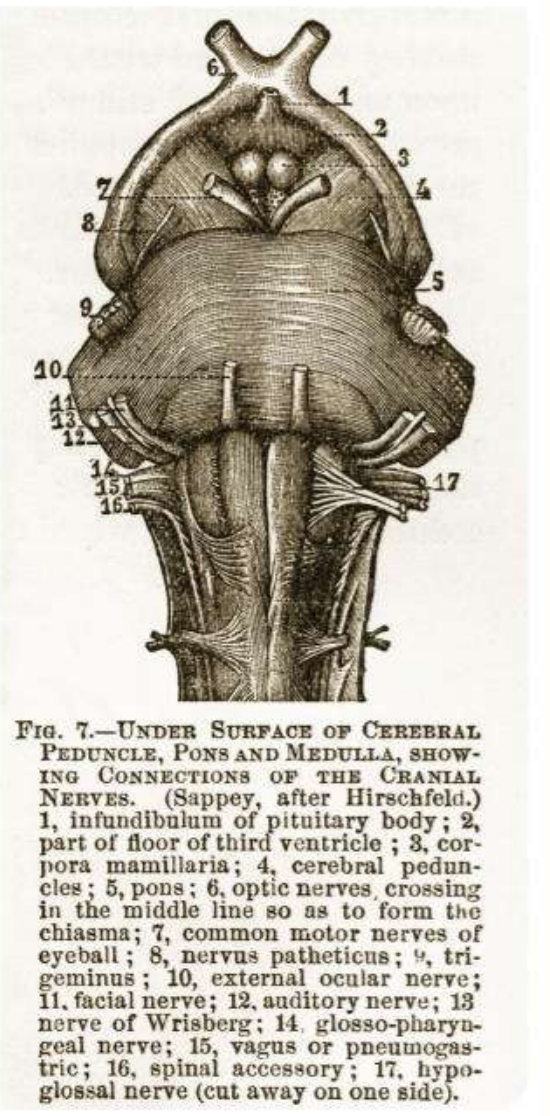


Fig. 7.—Under Surface of Cerebral Peduncle, Pons and Medulla, showing Connections of the Cranial Nerves. (Sappey, after Hirschfeld.) 1, infundibulum of pituitary body; 2, part of floor of third ventricle; 3, corpora mamillaria; 4, cerebral peduncles; 5, pons; 6, optic nerves, crossing in the middle line so as to form the chiasma; 7, common motor nerves of eyeball; 8, nervus patheticus; 9, trigeminus; 10, external ocular nerve; 11, facial nerve; 12, auditory nerve; 13 nerve of Wrisberg; 14, glosso-pharyngeal nerve; 15, vagus or pneumogastric; 16, spinal accessory; 17, hypoglossal nerve (cut away on one side).

The infundibulum of the pituitary gland is included in this Victorian anatomical illustration of the cerebral medulla

'MUCUS STORE'

Scientists have come a long way in their understanding of the pituitary gland and its many functions, but although it's only relatively recently that we have fully understood its importance, we've been aware of its presence for centuries. As long ago as 150 CE, Greek physician and philosopher Galen identified the gland and, noting its ability to secrete substances, suggested that its purpose was to help drain phlegm from the brain. By the early 18th century, doctors had discovered various anatomical elements of the gland, such as the hypothalamo-hypophyseal axis linking the pituitary gland to the hypothalamus – although at that time they were unaware how important this connection was. Various pituitary-related diseases were discovered across the 18th century, and by the mid-19th century Dr Martin Rathke described its formation. As time progressed, scientists discovered how vital the pituitary gland is to our survival and how it is manipulated by the hypothalamus.

DID YOU KNOW? Endocrine derives from the Greek words ‘endo’, which means inside or within, and ‘crinis’, meaning to secrete

synchronise the menstrual cycle, but also support cardiovascular health, bone health and brain function. The same can be said of the male hormone, testosterone, as it also supports bone health and muscle formation alongside general reproductive wellbeing.

When a person becomes pregnant, the endocrine system needs to work doubly hard as it is supporting two individuals and must finely balance the needs of the parent with the requirements of a developing foetus, while also accommodating the parent’s physical bodily changes. Many of the common complaints that arise during pregnancy, such as swollen ankles, heartburn, raised blood pressure and constipation, are all dealt with via hormones.

As we slide into old age, the endocrine system instigates more hormonal changes, which in turn causes a multitude of alterations and modifications to our bodies. Oestrogen levels lower, initiating menopause, a state

> **“Early treatment of a hormonal imbalance can prevent problems”**

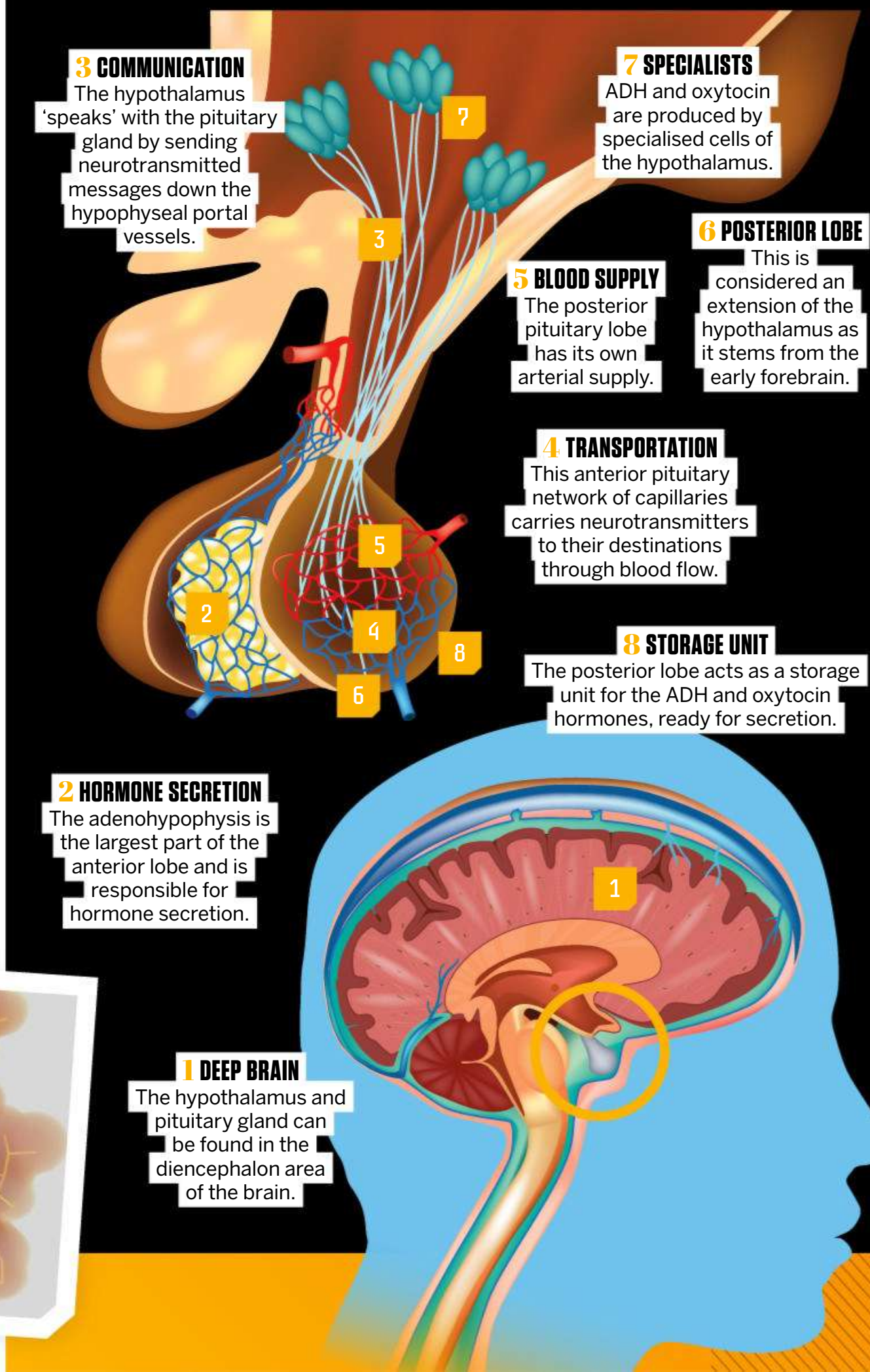
where the body can no longer reproduce. The growth hormone diminishes, as does testosterone, so both males and females become more clinically vulnerable. Bone density and muscle mass decrease and the immune system weakens. Glands within the endocrine system take longer to produce hormones and often secrete far less than when the body was younger, while the hormones themselves take far longer to break down. Such changes negatively affect the body’s functions, creating distressing characteristics in the elderly such as memory loss and osteoporosis.

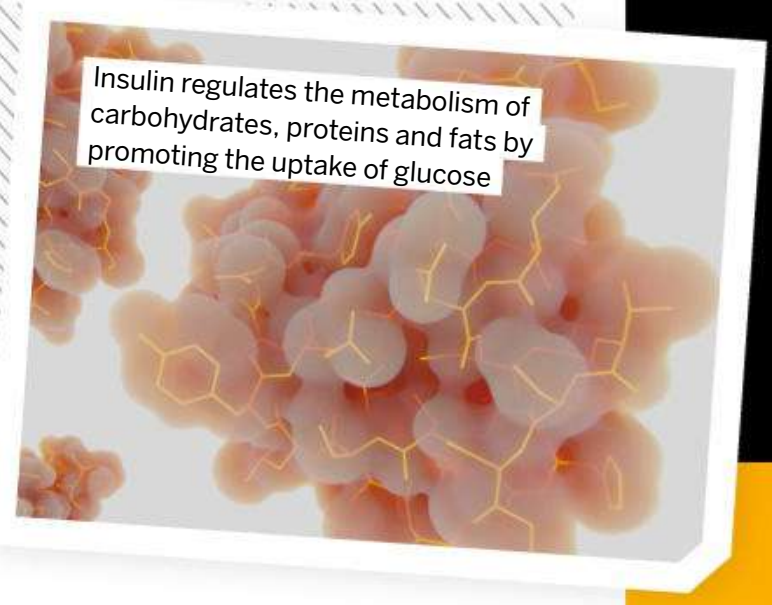
Without the endocrine system creating and secreting the many hormones that enter our bloodstream and ordering our organs and tissues to behave in a particular way, we wouldn’t be the fascinating and complex creatures that we are. So next time someone asks you why you’re being moody or why you need that extra hour in bed, you can answer truthfully... it’s my hormones.

THE MASTER GLAND

The pituitary gland is also known as the master gland since it oversees all other hormonal instructions. Hormones from the hypothalamus enter the hypophyseal portal, which connects the hypothalamus to the pituitary gland. A network of capillaries carry the hormones to the anterior lobe of the pituitary, where they start or stop the production of pituitary hormones.

These hormones stimulate various endocrine glands that control a multitude of bodily functions. The thyroid-stimulating hormone, for example, instigates parts of the body’s metabolism such as temperature control, while the human growth hormone sends instructions to the skeleton, the liver and the muscles. Two hormones, oxytocin and vasopressin, are sent to the posterior pituitary lobe. Vasopressin, or antidiuretic hormone (ADH), controls water loss in the body, while oxytocin is vitally important during childbirth. The pituitary gland works in conjunction with the hypothalamus to help our bodies deal with situations such as stressful events.




Insulin regulates the metabolism of carbohydrates, proteins and fats by promoting the uptake of glucose

© Getty / Alamy

GLANDS OF THE ENDOCRINE SYSTEM

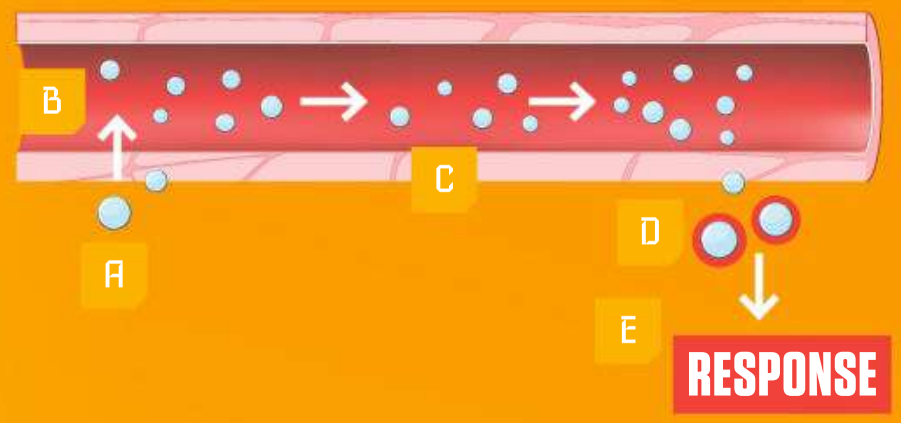
Eight major glands make up the endocrine system, and each one secretes a different hormone

ENDOCRINE OR EXOCRINE

While both the endocrine and exocrine systems produce and secrete hormones, the difference between them lies in the way they distribute hormones around the body. Unlike the endocrine system, the exocrine system doesn't rely on the bloodstream to transport hormones. It works outside of the bloodstream, planting the hormones directly onto an epithelial surface. This might be the outer layer of the skin – known as the epidermis – the lining of your intestines or the lining of your respiratory tract. The exocrine system achieves this by delivering hormones via a duct. These ducts can come in many different shapes and sizes, from simple to tubular, and can be individual or clumped together.

TARGETING CELLS

How do hormones know which cells to bind with and how do they get there?



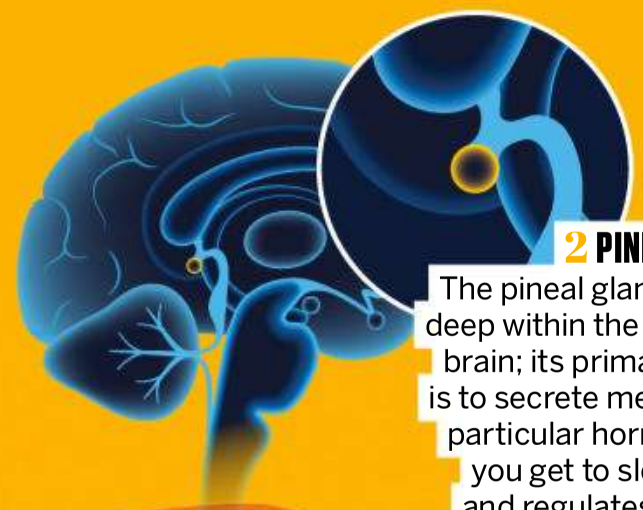
A THE ENDOCRINE GLAND
The hypothalamus instigates each ductless endocrine gland to produce a particular hormone.

B THE BODY'S HIGHWAY
The hormone is secreted directly into the circulatory system via the bloodstream, which acts as a road network.

C NON-TARGET CELLS
Without an appropriate receptor, the hormone will ignore a cell and keep moving along the bloodstream.

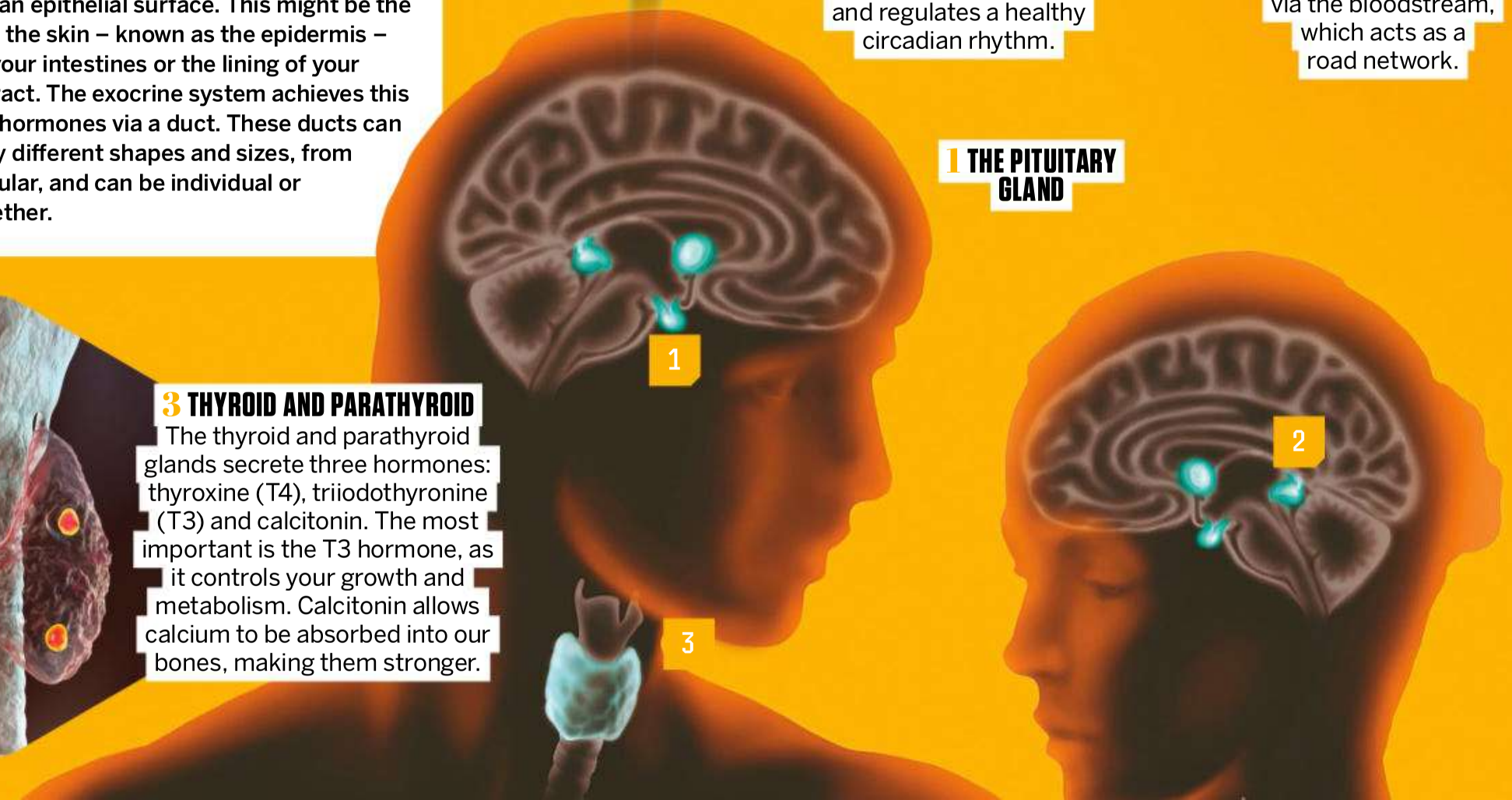
D THE TARGET CELL
Receptors on the cell's surface act like a beacon, informing hormones which organs they're intended for.

E THE BINDING PROCESS
The hormone binds with the target cell, triggering a series of reactions that will alter the behaviour of that cell.

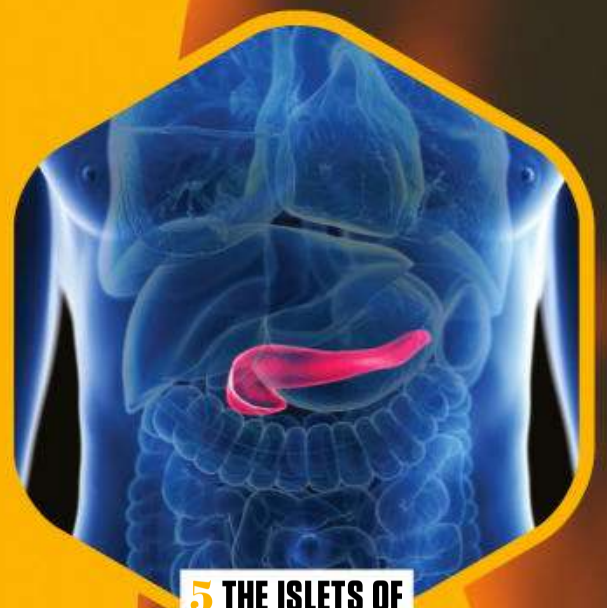


2 PINEAL
The pineal gland is located deep within the centre of the brain; its primary function is to secrete melatonin. This particular hormone helps you get to sleep easily and regulates a healthy circadian rhythm.

3 THYROID AND PARATHYROID
The thyroid and parathyroid glands secrete three hormones: thyroxine (T4), triiodothyronine (T3) and calcitonin. The most important is the T3 hormone, as it controls your growth and metabolism. Calcitonin allows calcium to be absorbed into our bones, making them stronger.

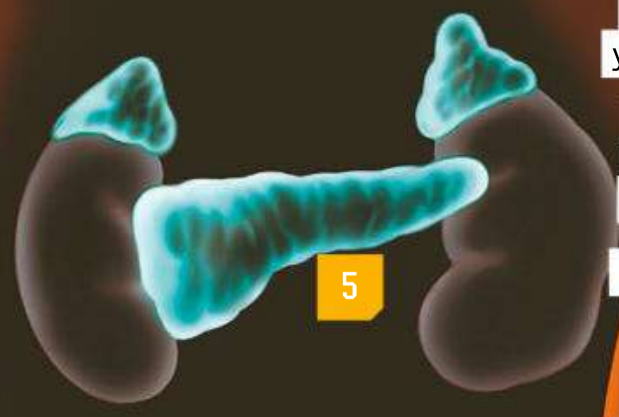


Did you know?
Too much alcohol can decrease testosterone levels



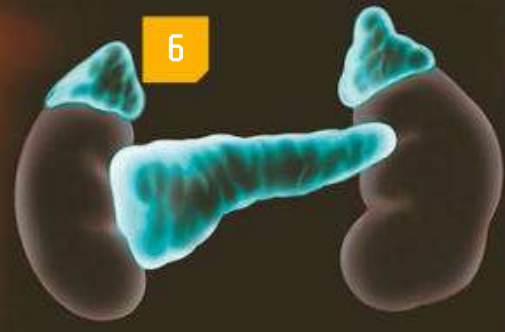
5 THE ISLETS OF LANGERHANS

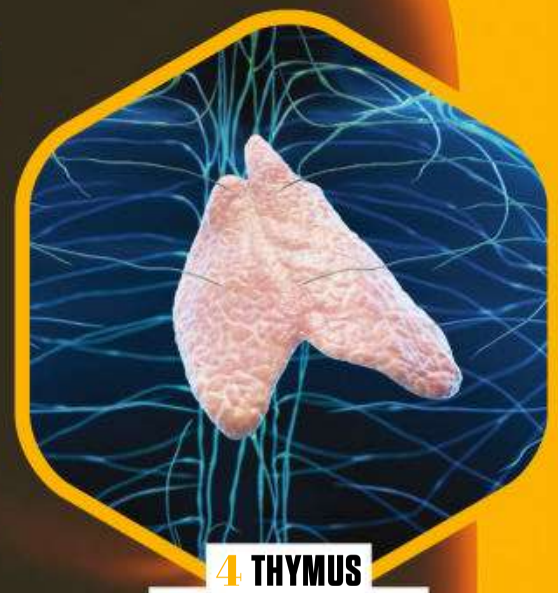
Islets of Langerhans cells create and release insulin, which acts to lower the blood sugar level, and glucagon, which raises blood sugar levels. In this way, glucose levels are maintained within the body.



6 ADRENAL

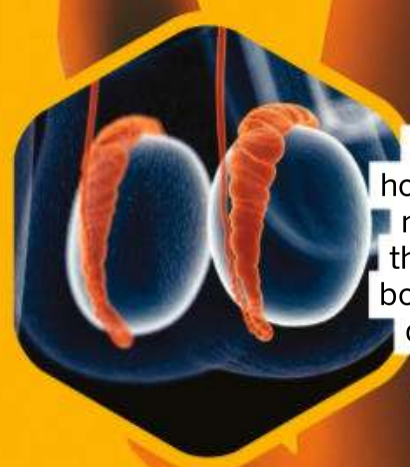
Adrenal glands, which are found at the tops of your kidneys, make vitally important hormones including epinephrine, cortisol, noradrenaline and aldosterone. These affect many bodily functions, including your oxygen intake, blood pressure and stress reactions. They also produce reproductive hormones.





4 THYMUS

Various hormones are made here: the thymopoietin, thymosin and thymulin help in the production of T-cells, while the thymic humoral factor supports the immune system. When enough T-cells have been produced, the gland begins to wither and is replaced with fat.



7 TESTES

The testes make the hormone testosterone in men, which instigates the growth of facial and body hair, develops a sex drive and helps in the creation of sperm.

8 OVARIES

The ovaries create and secrete the hormones oestrogen and progesterone in women, which help start the menstrual cycle and develop breasts at puberty. These hormones are also vitally important during pregnancy.

DID YOU KNOW? The pineal gland was once known as the third eye and was traditionally thought to connect people to the spiritual world

© Getty

IMBALANCES AND DISORDERS

The endocrine system plays a vital role in regulating biological functions. Any imbalance of hormones can have catastrophic results, leading to a variety of disorders

DIABETES

Diabetes occurs when the body is unable to produce the hormone insulin or use it effectively. This can lead to dangerously high blood sugar levels. Diabetes can occur in two forms: type 1 is an autoimmune condition that tends to develop in childhood or teen years. The body's immune system attacks cells in the pancreas, stopping the production of insulin. With type 2 diabetes, the body becomes resistant to insulin, causing a spike in blood sugar levels. Unlike type 1 diabetes, type 2 tends to occur in adults and can sometimes be brought about by eating too many sugary foods. Both type 1 and type 2 can be caused by a combination of genetic and environmental factors. Symptoms can include feeling exceptionally thirsty, having blurry vision, needing to urinate more frequently and feeling exhausted all the time. Long-term complications of diabetes can include cardiovascular disease and kidney damage.

PITUITARY GIGANTISM

This occurs when the pituitary gland produces far too much growth hormone in children before their bone growth plates fuse together. Muscle and organ size and height increase exponentially, causing the child to become abnormally big for their age. It can also cause many other symptoms, including excessive sweating and double vision.

ADDISON'S DISEASE

This occurs when the adrenal glands fail to produce the required amounts of the hormones cortisol and aldosterone. For this reason it is also known as primary adrenal insufficiency. The symptoms include low blood pressure, muscle weakness and overwhelming tiredness. Addison's disease can be caused by any damage to the adrenal glands.

POLYCYSTIC OVARY SYNDROME

Scientists aren't sure of the exact cause of polycystic ovary syndrome, but they have noticed a correlation between women who suffer with the disease and an increase in the hormone insulin. Some women create more insulin than is necessary because their bodies are resistant to it. This instigates an increase in another hormone, testosterone. When this occurs, the patient may suffer from excessive facial hair and weight gain, and may also find it very difficult to fall pregnant. This is due to infrequent ovulation cycles, and sometimes the body can stop ovulating altogether.

DID YOU KNOW? Endocrinology was first practised by Chinese healers 2,000 years ago when they extracted hormones from urine

FOUR TO SIX WEEKS

Thyroxine can stay in the body for over a month

50

The number of different types of hormones in the body

100 YEARS

The term 'hormone' was coined a century ago

THE BRAIN SECRETES ATRIAL AND NATRIURETIC PEPTIDES, WHICH DECREASE BLOOD PRESSURE

500 TO 900MG

The pituitary gland can weigh just shy of a gram

ALL MAMMALS, BIRDS AND FISH HAVE AN ENDOCRINE SYSTEM

Swollen thyroid glands act as a warning of a hormonal imbalance and potential disease

Did you know?

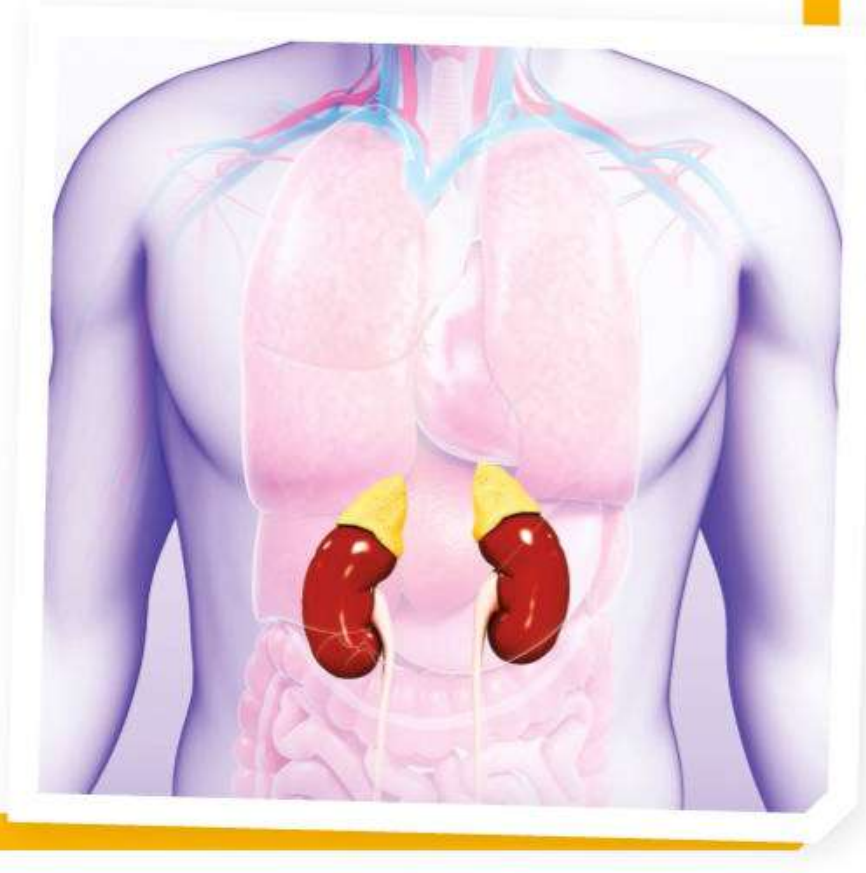
Diabetes was once diagnosed by tasting urine

THYROIDISM

This can present itself as hyperthyroidism or hypothyroidism. Both conditions concern the thyroid gland and the production of the thyroid hormone, but they are very different diseases. Hyperthyroidism occurs when the thyroid gland secretes too much thyroid hormone. The thyroid becomes overactive, and this causes the person to be overly nervous with an increased heart rate. They tend to lose weight without trying to and will often sweat excessively. This can sometimes be caused by an autoimmune disorder known as Graves' disease. Hypothyroidism, on the other hand, occurs when the thyroid gland is underactive. The body becomes sluggish and the gland produces too little of the thyroid hormone. The patient becomes extremely tired and other bodily functions slow down. For example, they can suffer from intestinal issues such as severe constipation. The skin can become very dry and patients will often become depressed. It will also result in weight gain.

SPONTANEOUS CUSHING'S SYNDROME

Cushing's syndrome occurs when your body makes too much cortisol hormone, which is made by the adrenal glands. This can happen if the pituitary gland is aggravated by something, such as a benign tumour. The pituitary gland releases too much adrenocorticotropic hormone (ACTH), which is sent to the adrenal glands via the bloodstream. The ACTH commands the adrenal glands to make extra cortisol that the body doesn't need. Symptoms include weak bones, sudden weight gain and a darkening of the skin's pigmentation. The problem can usually be solved by removing the tumour.



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HOW SAMURAI SWORDS WERE MADE

Katana, the traditional blades of a Japanese samurai warrior, were forged to meticulous standards and gave their owners high status

WORDS AILSA HARVEY

5 FACTS SWORD STANDARDS

1 SHARP SIDE UP
The sharp edge of the sword always needs to face upwards, whether it's placed on a stand or being worn on the body.

2 DISPLAYING INTENTION
If the handle, also called the 'tsuka', is on the left-hand side of the samurai, it portrays peace, while the right side indicates that the samurai is ready to attack.

3 BOWING OUT
Retired samurai had their swords taken away and were required to bow to anyone with one for the rest of their lives.

4 DRAWING RULE
If a samurai pulled their katana out of the sheath by at least nine centimetres, this was classed as officially drawing the blade.

5 DYING WITH HONOUR
If samurai didn't abide by the rules, they were ordered to commit seppuku, also called hara-kiri. This was thought to be an honourable death, where the samurai would slice open their own stomach.

Did you know?
High-quality katana take 18 months to make

5amurai warriors ruled Japan from 1185 to 1868, replacing the government and introducing immense discipline and loyalty to the military in the absence of a police force. To be a samurai, warriors needed to abide by the ethic code of 'bushidō', which translates to 'the way of the warrior'. Included in this code were eight virtues that the samurai lived by: justice, courage, mercy, respect, honesty, honour, loyalty and self-control. While these sound like positive traits, samurai took bushidō to the extreme. Samurai couldn't show any sign that they were afraid of death – a mistake on the battlefield might force a samurai to honour his name and end his own life. This was viewed as a much more desirable outcome than losing their samurai status.

The most important weapon a samurai owned was their sword, called a katana. While the other weapons samurai used to fight with were important in attaining victories, no other weapon was as personal to them as their sword. The katana was worn at all times, as if it were part of the warrior. Used mostly for open combat, these swords were typically between 100 and 110 centimetres in length and required two hands to use. Bushidō dictated that a samurai must show righteousness, only attacking an enemy when there was an important reason. This meant that they were unlikely to attack with their katana on a whim. However, if they believed their honour had been compromised, the code of conduct allowed them to strike anyone of a lower rank than themselves.

Top to bottom, these are the katana, wakizashi and tantō

JAPANESE SWORDS IN COMBAT

Although they also used weapons such as guns, spears and a bow and arrow, ancient samurai warriors relied on their swords. There was more than one class of samurai sword. The five main types were the katana, wakizashi, tantō, ōdachi and tachi. The best known samurai sword is the curved katana, which is designed to be used with two hands and make contact with an opponent from over a metre away. Wakizashi are similar in appearance to katana, but they are around half the length. These two swords were often worn by samurai as a pair.

The tantō is more akin to a dagger than a sword. This small stabbing weapon became largely decorative towards the end of the 1800s. On the opposite end of the scale is the ōdachi, which means 'field sword'. This weapon was longer than the katana and was used by soldiers fighting on foot in fields. Tachi were the predecessors of katana, and were longer, with a more curved shape. This made the blades ideal for reaching down to attack soldiers while samurai rode on horseback. When katana were introduced, tachi became less common.

© Getty

A PERFECTED PROCESS

The traditional manufacturing of a single blade is a lengthy process. It requires swordsmiths to perfect the metal chemistry for a quality blade and incorporate intricate artwork. Steel is produced by smelting iron sand and charcoal in a clay furnace, applying intense heat to the metal ore to extract the base metal. The furnace is monitored and fed with material constantly over 72 hours. When smelting is complete, the clay furnace is broken apart and the steel inside sorted based on its carbon content. The strongest steel is delivered to swordsmiths, who heat, hammer and fold the metal around 16 times, purifying it. Different categories of steel are heated and shaped to form the blade. The sword is covered in clay and charcoal powder, then fired at a temperature of 815 degrees Celsius. This gives the sword a strong and fixed coating. Immediately after the final coating, the sword is dunked into cold water. As the different steel types cool at different rates, the blade hardens with a slight bend. Lastly, the sword is polished with hard stones. These sharpen the blade, now ready to be mounted onto its handle.

A Japanese swordsmith covering a blade in a layer of hot steel slurry

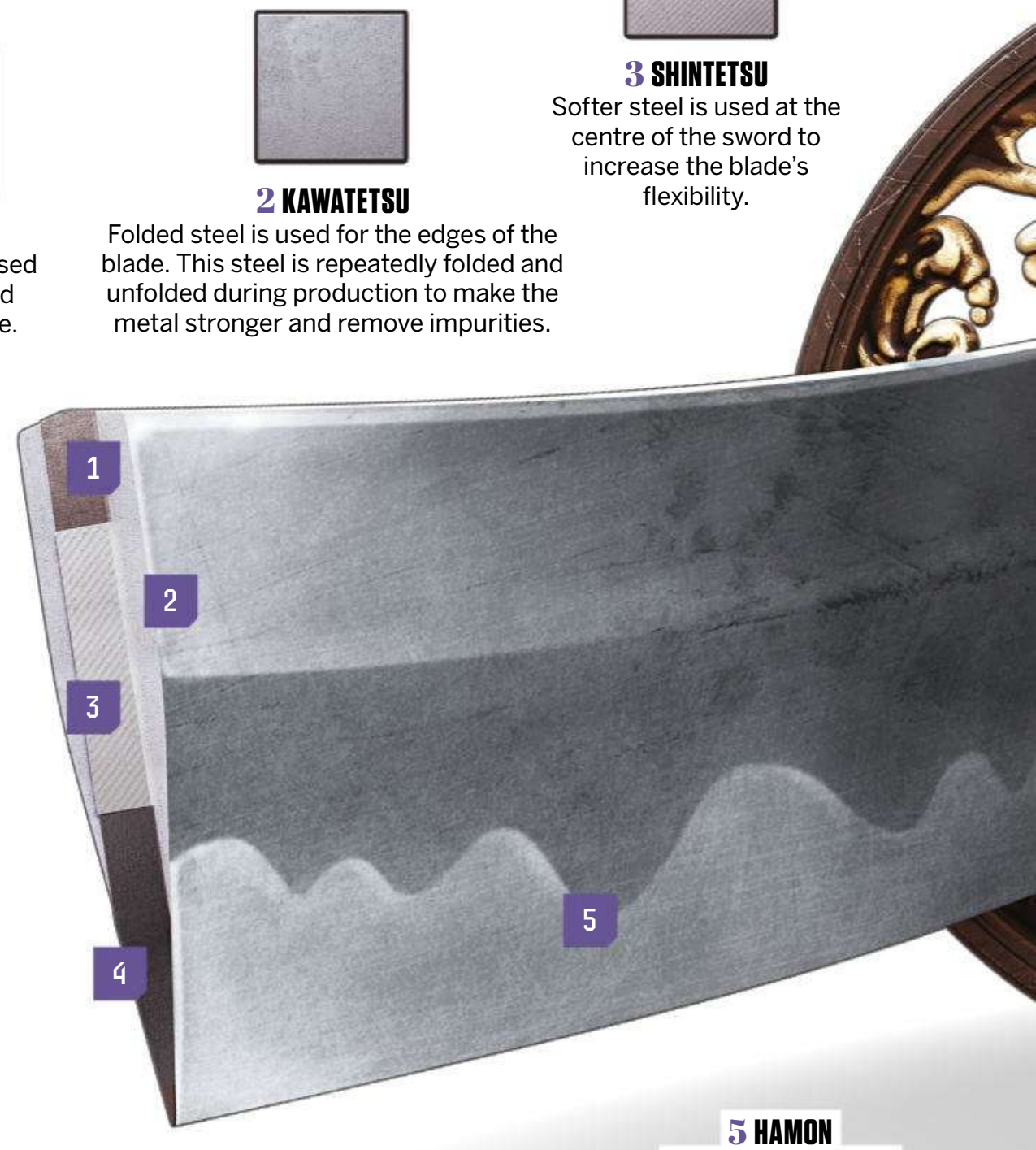
BLADE ANATOMY

Explore the structure and intricate designs of katana

1 MUNETETSU
Medium steel is used at the centre and back of the blade.

2 KAWATETSU
Folded steel is used for the edges of the blade. This steel is repeatedly folded and unfolded during production to make the metal stronger and remove impurities.

3 SHINTETSU
Softer steel is used at the centre of the sword to increase the blade's flexibility.



4 HATETSU
The tip of the blade requires the hardest steel to make a clean slice through the target.

5 HAMON
A pattern is created on the blade during the hardening process.

TYPES OF JAPANESE BLADES

Compare the structure and assembly of some of Japan's traditional swords

1 MARU
This is the most common blade, only made from one type of high-carbon steel. It is the simplest and easiest to manufacture.

2 KŌBUSE
Shigane steel is used for the core and hagane steel for the exterior. Hagane is a strong and durable steel, while shigane adds flexibility.

3 HONSANMAI
This is similar to a kōbuse blade, but has the addition of a third folded steel type at the sides, called kawagane.

4 SHIHŌZUME
Shihōzume blades have hard steel positioned at both edges of the blade. This adds strength and prevents blade breakage.

DID YOU KNOW? There are only around 180 traditional Japanese swordsmiths working today

6 TSUBA
This sword features a guard that protects the samurai's hand and assists in balancing the heavy weapon.

7 TSUKA
This is the sword's hilt. Usually this is wooden and wrapped in ray skin for grip.

Did you know?

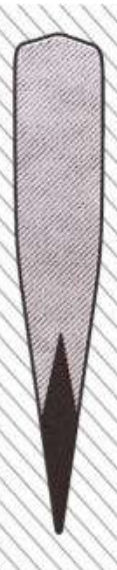
Modern Japanese swordsmiths undergo five years of training

"The most important weapon a samurai owned was their sword"

MORE THAN A WEAPON

To ancient samurai warriors, swords weren't just weapons, but symbolised their souls. A katana was a show of class, with customised sword designs displaying patterns representative of their wielder's status. The way the katana was worn was also significant in demonstrating rank. Only the highest ranking warriors carried their swords horizontally, while lower classes had to carry their blades closer to their bodies in a vertical position. Samurai carried a long and short sword – the long one unique to them and their soul and the smaller one being passed down through generations. Owning a samurai sword was viewed by warriors as a symbol of purity. By carrying and using the blades, samurai believed they warned off evil spirits.

5 MAKURI
Makuri means 'rolling', and this type of blade consists of a durable steel rolled in hard steel.



6 WARIHA TETSU
The hard tip of the blade is inserted into the softer steel, rather than being added onto the flat top.

7 ORIKAESHI SANMAI
This sword type contains hard, soft and folded steel, with the two halves being forged together vertically.

8 GOMAI
The gomai blade gains strength from its sandwich-style composition. The flexible steel is between two layers of hardened steel.

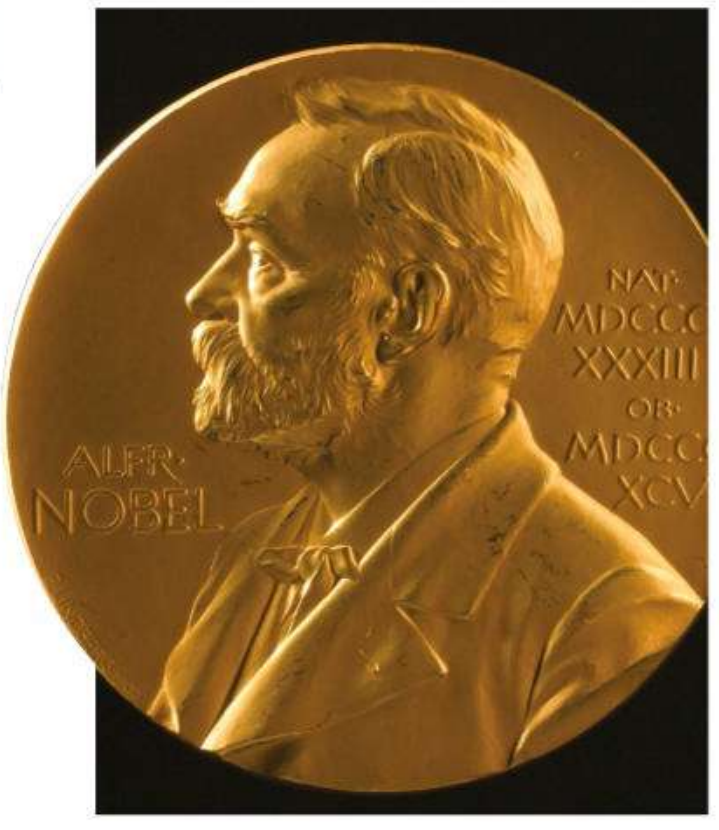
9 SOSHU KITAE
These swords appear similar to kōbuse blades, but they have additional layers of folded steel beneath their hard-steel sides.

© Alamy / Getty / Illustration by Nicholas Forder

ALFRED NOBEL

Meet the man behind the prestigious Nobel Prize and discover its explosive origins

WORDS **SCOTT DUTFIELD**



Above: An example of a Nobel Prize for Physics medal, awarded to British physicist Joseph John Thomson in 1906

Right: A portrait of the Swedish inventor and philanthropist Alfred Nobel

Alfred Nobel was born on 21 October 1833 in Stockholm, Sweden, to engineer Immanuel Nobel and his wife Andriette. In 1842, Alfred and his mother moved to St Petersburg to join his father, who had moved to Russia to pursue a slew of successful engineering ventures, including providing materials for Russian military underwater mines. Once there, Alfred received a first-class education from private educators and showed an aptitude for the sciences, languages and literature.

To discourage a growing interest in poetry and literature, Alfred's father sent him to travel across Europe and the US in the early 1850s to further his studies in chemical engineering. While in France, Alfred spent time at the Paris laboratory of chemist Théophile-Jules Pelouze beside an Italian chemist named Ascanio Sorero, who had been working with an explosive chemical called nitroglycerin. During Alfred's travels, the Crimean War had caused Immanuel's business to boom, but once the war ended it quickly went into bankruptcy, driving Immanuel to move his enterprise back to Sweden. Continuing with the family's aptitude for working with explosives and bringing with him knowledge of a new explosive compound, Alfred moved back to Sweden in 1863 and began producing nitroglycerin for use in the construction industry. Unfortunately, an explosion in one of the nitroglycerin factories killed several workers, including Alfred's brother Emil Nobel.

The loss of his brother compelled Alfred to develop a safer, more stable form of nitroglycerin, which became a moldable putty he named dynamite. The invention of dynamite sticks coincided with the development of the pneumatic drill and diamond-tip drilling. Alfred's dynamite sticks quickly became popular because they could safely blast rock for tunnel and canal construction at a low cost. Along with the invention of dynamite, Alfred and the Nobel family created a whole host of different explosives, including dynamite gelatine and a smokeless version of gunpowder. However, his most memorable contribution to science has been through the work of others.

Just a year before his death, Alfred penned his last will and testament, which changed the world

Did you know?

The youngest Nobel Prize winner was 17 years old

The BIG idea

MAKING DYNAMITE

A stack of Nobel's 'Extradynamit' sticks, sold in Stockholm during the 19th century

Alfred Nobel is known as the father of dynamite. He experimented extensively with a highly explosive chemical called nitroglycerin. To make nitroglycerin, Nobel carefully combined glycerol – a naturally occurring alcohol derived from fat and oils – with nitric and sulphuric acid. The resulting chemical contains plenty of oxygen, carbon and nitrogen, making it a molecular cocktail for energetic explosions. To control the volatility of the chemical, Alfred combined nitroglycerin with a type of silica, called kieselguhr, and created a stabilised paste he called dynamite. Dynamite could then be inserted into drilling holes and exploded using another of Alfred's inventions, a blasting cap, which ignited the rod of dynamite using a lit fuse.

5 THINGS TO KNOW ABOUT THE FIRST NOBEL PRIZE WINNERS

1 WILHELM CONRAD RÖNTGEN
PHYSICS
Röntgen won the Nobel Prize for discovering X-rays and using them to image the bones in the human hand.

2 EMIL VON BEHRING
MEDICINE
Behring developed the first effective therapeutic serum against serious infection caused by a bacteria called diphtheria.

3 JACOBUS HENRICUS VAN 'T HOFF
CHEMISTRY
Awarded for discovering osmotic pressure and its importance for plants and animals.

4 SULLY PRUDHOMME
LITERATURE
Prudhomme received the prize for his poetry, which the Nobel Foundation said "gives evidence of lofty idealism, artistic perfection and a rare combination of the qualities of both heart and intellect."

5 HENRY DUNANT AND FRÉDÉRIC PASSY
PEACE
Awarded to the founder of the International Committee of the Red Cross and the founder of the French Society of Peace.

DID YOU KNOW? From 1901 to 2022, 989 people and organisations have been awarded a Nobel Prize

forever. A wealthy man, Alfred had an estimated net worth of more than 31 million Swedish krona – equal to more than £126 million ($157 million) in today's currency – the majority of which was allocated to the creation of a fund to support the work of scientists and scholars around the world, now known as the Nobel Prize. The prize is awarded by the Nobel Foundation and recognises intellectual achievements across six categories: physics, chemistry, medicine, literature, peace and economic science. The winner receives a gold medal, a diploma and a monetary award.

There is speculation among historians as to Alfred's motives for creating the fund. Some cite a French newspaper that branded him the 'merchant of death' for the wealth he had gained in inventing hazardous dynamite, and Alfred wished to remedy this reputation. Others believed his interest in creating the fund was shaped long before his will was written as a way to pay his fortune forward after receiving an award from the Royal Swedish Academy of Sciences. On 10 December 1896, Alfred Nobel died at the age of 63 in Sanremo, Italy, following a stroke that left him partially paralysed.

A LIFE'S WORK

From explosions to awards

1833
Alfred was born into a family descended from Swedish scientist Olaus Rudbeck.

1850
Alfred began his experiments with an explosive chemical called nitroglycerin.

1864
The Nobel family began mass producing nitroglycerine as a gunpowder substitute.

1867
Patent 102 for the design for dynamite, or 'Nobel's gunpowder', was obtained.

1875
Alfred created blasting gelatin, a more powerful dense suspension of nitroglycerine.

1887
A French patent for a black, smokeless powder made from nitroglycerine, called ballistite, was obtained by Alfred.

1895
Alfred made his will, with 94 per cent of his assets used to create a honours fund.

1896
Having suffered from ill health towards the end of his life, including a serious heart condition, Alfred passed away.

1900
The Nobel Foundation was established to fulfil the intentions of Alfred's will.

1901
The first winners of the Nobel Prize were awarded their medals.

© Getty

GREEN HOME ENERGY

From small-scale installations to carbon-neutral houses, how the different ways we heat and power our homes impact the planet

WORDS AILSA HARVEY

DID YOU KNOW? Hydropower is the most widely used form of green energy worldwide

Whether you're boiling a kettle for your mid-morning brew, catching up on your favourite television show or turning the radiators up a notch to escape colder weather, many of the utilities inside your home use precious energy. In this modern age, it's near-impossible to live without consuming energy, but what we can control is where we source this from.

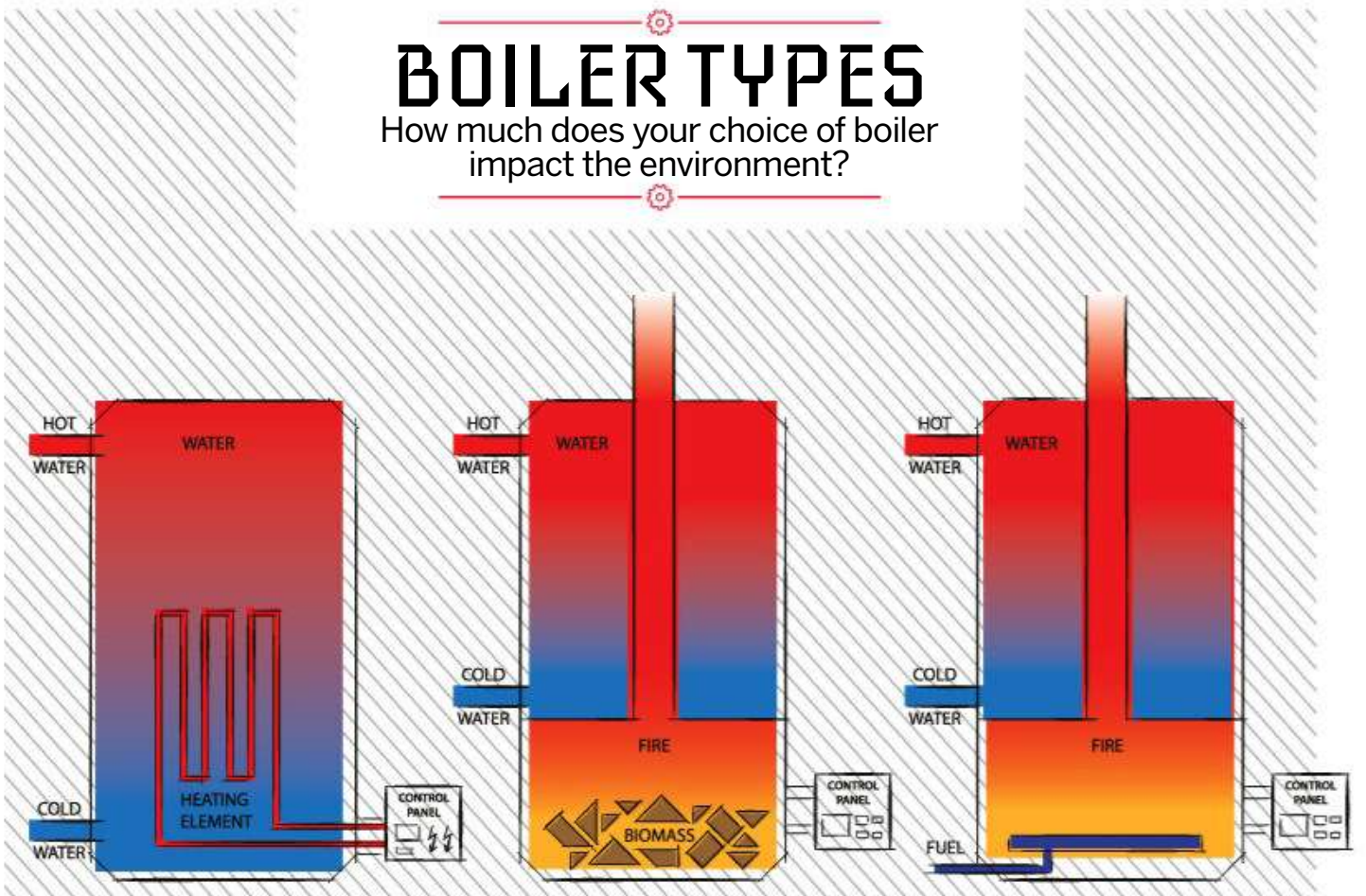
Fossil fuels such as coal, gas and oil were some of the earliest sources of energy. Since ancient times, burning coal was used to heat homes as it burned for longer periods than wood. Since then, humans have continued to mine coal. It's a primary source of fuel for electricity production, while other fossil fuels like gas are used to heat water in our homes.

As the world's population has increased, the demand for fossil fuels has too. Today, not only are they running out, but the harmful emissions from burning these fossil fuels to support the energy needs of over 8 billion people is having a dire impact on the planet. It's now well known among scientists and the general public that heating houses using fossil fuels contributes significantly to greenhouse gas emissions and the warming of Earth.

But thanks to the innovative work of renewable energy engineers, living comfortably doesn't have to come at the expense of the environment. Natural and clean sources of energy from flowing bodies of water, wind and sunshine can also be converted into a limitless source of electricity, increasingly taking over from burning fossil fuels.

BOILER TYPES

How much does your choice of boiler impact the environment?



1 ELECTRIC

Cold water enters the boiler and is heated inside by electricity instead of burning gas or oil. This has an energy efficiency of around 99 per cent.

2 BIOMASS

This boiler involves the burning of wood pellets, wood chips or logs to heat water. The process still releases carbon dioxide, but it uses a more renewable material with much lower carbon emissions. Growing the plant materials for biomass boilers also captures some carbon.

3 GAS

Most UK homes have gas boilers. An average household using this boiler emits around 2.2 tonnes of carbon dioxide every year. They are rarely more than 93 per cent efficient.

Modern green-roof technology was invented in the 1960s

GREEN-ROOF HOMES

Some buildings have flat roofs entirely covered in plants. As well as being easier on the eye, this design feature helps insulate homes, keeping warm air in and soundproofing them. As the plants grow, they absorb solar heat instead of reflecting it away from the building as typical roofs do. The trapped air that gets stuck between the individual plants serves as a natural insulator. Green roofs have extra benefits, such as providing more natural habitats for wildlife, absorbing water to reduce the load on drainage systems and improving sound insulation to block out weather and traffic noises. Sound waves with lower frequencies are blocked by the soil in the roof, and the plants themselves absorb higher frequency sound waves.

Did you know?

98 per cent of Norway's energy is from renewable sources

© Getty / Alamy / Shutterstock

SUPER-GREEN ECO HOMES

1 ECO ARCH KENT, ENGLAND

This house's arched shape bears heavy loads with reduced materials. 26,000 clay tiles, covered with a green roof, provide good insulation. Solar energy powers the electricity and hot water.

2 KINGSPAN LIGHTHOUSE WATFORD, ENGLAND

This is a net-zero carbon home. In the ceilings is phase-changing material that absorbs the heat in the rooms and reverses the process to release it into the rooms at night.

3 SLIP HOUSE LONDON, ENGLAND

The boxes in this low-energy house's design are staggered to optimise the area where light can enter the building.

4 SUPERADOBE CALIFORNIA

Homes built with sandbags and covered in ceramic, like this one in Hesperia, California, eliminate the need for wood in construction, reducing deforestation.

5 MALATOR EARTH HOUSE PEMBROKESHIRE, WALES

For a minimal impact on the surrounding landscape, Malator is built into the Welsh hills. It has a large window to keep the home well lit.

2 WIND TURBINES

These turbines are installed outside homes. Even small amounts of wind can turn the aerodynamic blades. The kinetic energy produced by rotation is turned into electrical energy by a generator.

1 PHOTOVOLTAIC PANELS

When light particles from the Sun hit these panels, electrons are released and an electric current is generated.

3 GEOTHERMAL HEAT PUMPS

Ground-to-water heat pumps transfer heat trapped in the ground below homes to water inside pipes. This heated water can be used for naturally sourced underfloor heating.

Did you know?

Hydro Genies help radiators generate 20 per cent more heat

5 DRAUGHT-PROOFING

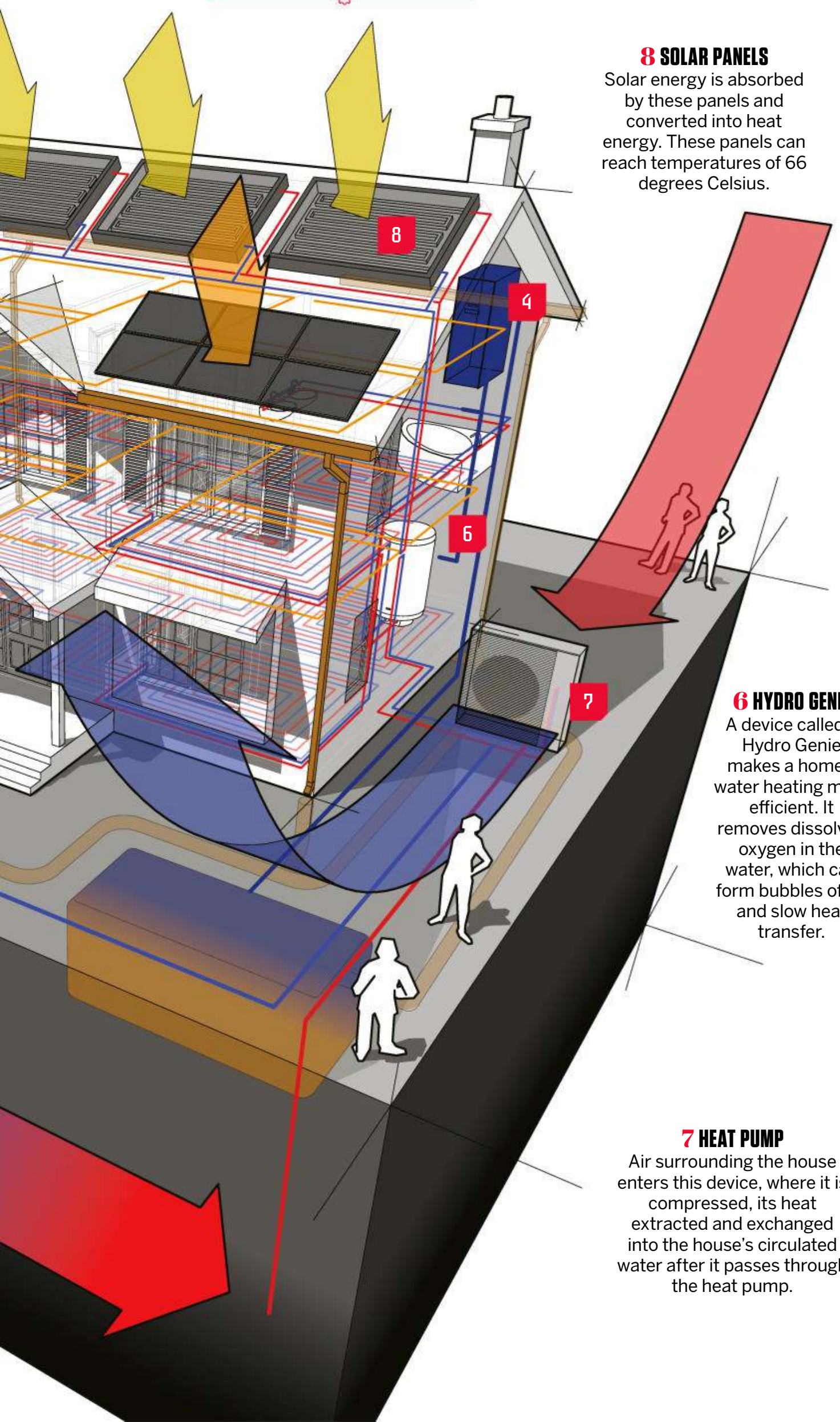
Old buildings can lose up to 20 per cent of their internal heat due to draughts. Adding secondary glazing to old windows can prevent this and lower energy usage.

"In this modern age, it's near-impossible to live without consuming energy"

DID YOU KNOW? In one year, a single wind turbine can generate power for 1,500 homes

SMART AND SUSTAINABLE LIVING

Peer inside an eco-friendly house to discover the technologies that utilise and protect the environment



4 RAINWATER HARVESTING

A tank collects rainwater from gutters as it runs off the rooftop. This can be used in the garden or delivered to toilet cisterns as flushing water.

8 SOLAR PANELS

Solar energy is absorbed by these panels and converted into heat energy. These panels can reach temperatures of 66 degrees Celsius.

6 HYDRO GENIE

A device called a Hydro Genie makes a home's water heating more efficient. It removes dissolved oxygen in the water, which can form bubbles of air and slow heat transfer.

7 HEAT PUMP

Air surrounding the house enters this device, where it is compressed, its heat extracted and exchanged into the house's circulated water after it passes through the heat pump.

MAKING CLEAN ENERGY ACCESSIBLE

One of the main reasons why so many people in Europe rely on gas boilers is because sustainable options, such as heat pumps, are generally much more costly to install. However, with the climate crisis and energy crisis combined, both governments and companies are thinking more about how to make green energy solutions affordable and accessible. Aira is a home energy company that launched in June 2023, dedicated to replacing Europe's widespread gas boilers with air-to-water heat pumps. Daniel Särefjord, the chief executive of Aira in the UK, explains that "residential buildings account for ten per cent of the total direct emissions in Europe". The UK, which has more than 20 million residential homes, uses gas because it is "artificially cheap," Särefjord says, explaining that heat pumps are a less expensive option for long-term use. Generally, heat pumps maintain the same internal temperatures as traditional gas boilers, but are a cleaner alternative. Air-to-water types are easier to install as they can be connected to the radiator system already in place. Making it easier to choose green energy technologies for our homes has the potential to drastically lower human impact on the environment. Theoretically, if everyone in the UK replaced their gas boiler with a heat pump, nearly 37 million tonnes of carbon dioxide could be prevented from entering the atmosphere a year.

Heat pumps can absorb heat from the air, even in temperatures as low as -20 degrees Celsius

© Getty / Alamy / Shutterstock / The Modern House

HOW TO DETECT LANDMINES

The technology behind the hunt for hidden explosives

WORDS SCOTT DUTFIELD

They're usually found planted beneath the surfaces of fields, forests and pathways in countries in conflict or still affected by the remnants of war: landmines are some of the most sneaky and dangerous weapons around. From triggering ground-based blasts to igniting a fireball at head height, these explosives have been designed to take out their target in many different ways. Most landmines work using a metal or plastic casing that's filled with an explosive charge. When a person's foot or the caterpillar tracks of a tank hit a pressure plate at the top of the landmine, it triggers the explosion. As well as being a tool used in active warfare, landmines are often forgotten about by those who plant them. Due to their robust design, they can remain active for decades. Mines aren't often planted alone, set up in minefields to block enemies from moving through certain areas.

Did you know?

Landmines kill around 70 people every day

Finding a minefield can be tricky, as the surface may at first look safe enough to travel along. To detect any threats, military personnel use several tools and devices to identify and remove mines before they detonate, including autonomous robots and handheld sweepers. These aren't too different to the commercial metal detectors used on beaches. Like traditional metal detectors, they generate an electromagnetic field that interacts with metal objects, such as a landmine, and then alerts the holder. But metal detecting alone isn't always the most efficient way to find landmines, as the sweeper will also detect any buried scrap metal it encounters. To be more effective, many minesweepers also incorporate a ground-penetrating radar that sends radar pulses into the ground and records any pulses that bounce off buried objects. These bounced-back energy waves are used to build a picture of the subsurface and reveal any hidden landmines.

An uncovered blast landmine

A soldier on the hunt for landmines buried beneath the sand

DID YOU KNOW? It's estimated that there are around 110,000,000 undiscovered landmines worldwide

WHAT LURKS BENEATH

How handheld sweepers use electromagnetism to reveal hidden dangers

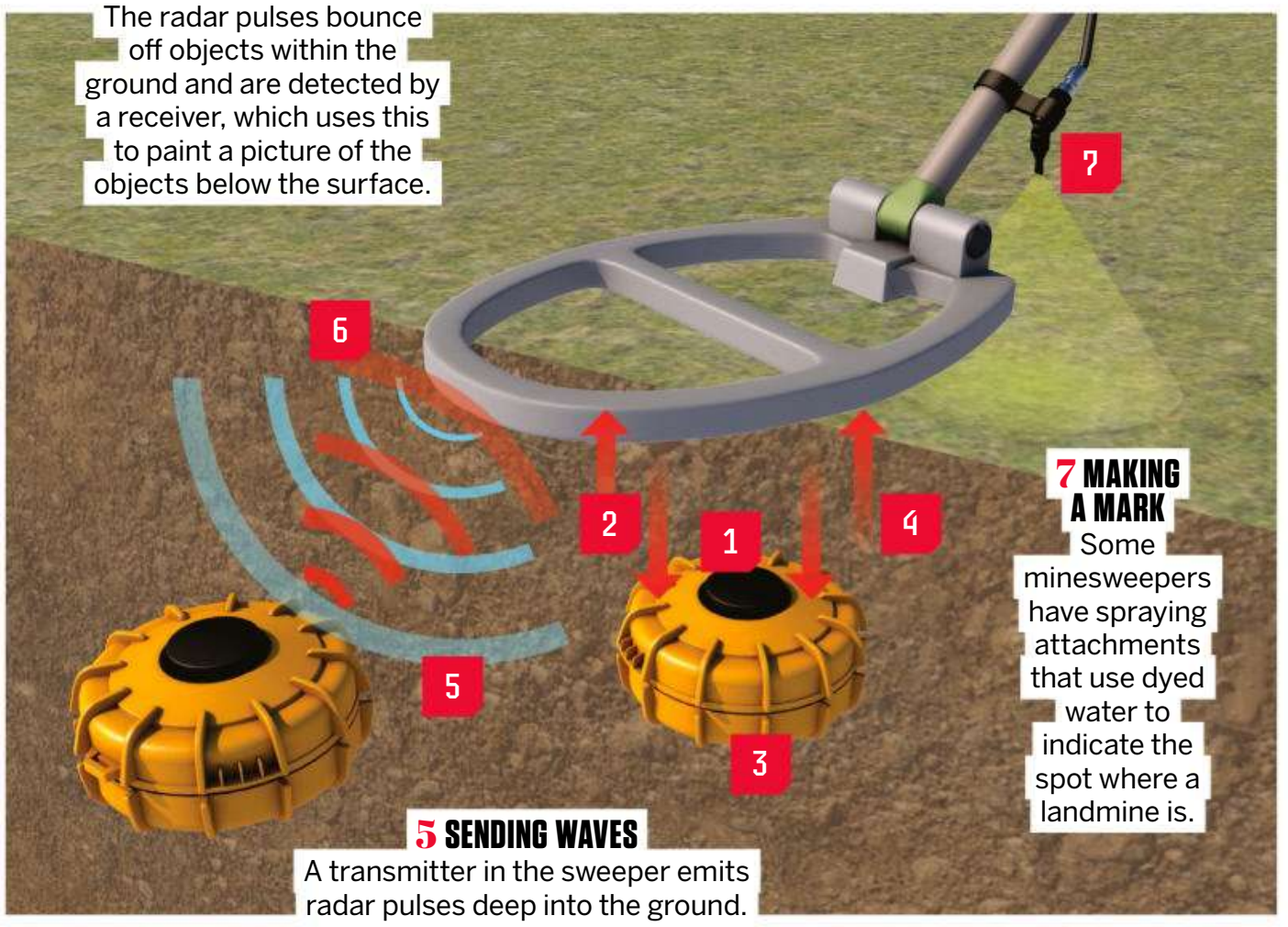
1 LANDMINES
Landmines come in all different shapes and sizes, some made from metal and others made from plastic.

2 MAGNETIC FIELD
The sweeper passes an electrical current through a coil to create an electromagnetic field, which penetrates the ground.

3 EDDY CURRENTS
When a conducting metal object such as a landmine is exposed to an electromagnetic field, electrical currents called eddy currents form.

4 RETURNING MAGNETIC FIELDS
The eddy current generated in the landmine creates its own weak electromagnetic field, which the sweeper can detect, revealing the presence of a metal object.

6 RETURNING WAVES
The radar pulses bounce off objects within the ground and are detected by a receiver, which uses this to paint a picture of the objects below the surface.



7 MAKING A MARK
Some minesweepers have spraying attachments that use dyed water to indicate the spot where a landmine is.

5 SENDING WAVES
A transmitter in the sweeper emits radar pulses deep into the ground.

RODENT MINE HUNTERS

It's not just machines that can spot a concealed landmine: it turns out that rats are also great at sniffing them out. More than 60 countries have areas with hidden unexploded mines that have been left behind after conflict. To help uncover as many of these dangerous landmines as possible, an organisation called APOPO has been training African pouched rats to find landmines for over 26 years. During training, rats are taught to recognise the odour of trinitrotoluene (TNT), an explosive compound used in landmines. Trained 'HeroRATs' are light enough to avoid setting off a landmine and can scurry safely through minefields while attached to a series of leads, sniffing out mines. In just 30 minutes a single HeroRAT can cover the same area that a human could with a metal detector in four days.

A HeroRAT sniffing out landmines in a minefield

An earlier model of Mine Kafon's Manta drone

DRONE DETONATORS

What if you could detect and detonate landmines without having to set foot anywhere on a minefield? Organisations from around the world are developing drone systems that can uncover hidden landmines and remotely detonate them. One such company, Mine Kafon, has created the Manta drone, an autonomous device that uses 3D-generated maps to systemically move across a potential minefield. As it does, it uses both metal-detecting sensors and ground-penetrating radar to locate landmines. When the drone has located a landmine in a minefield, it can be fitted with a robotic arm to drop an explosive charge above the mine to detonate it. The detonation process is not autonomous, instead being remotely controlled by a human pilot.

© Alamy / Getty / Illustration by Adrian Mann

FASCINATING FRUIT

From the stench of the durian to the flavour-changing ability of miracle berries, discover the wonderful world of fruit

WORDS SCOTT DUTFIELD

DID YOU KNOW? The smallest known fruit is watermeal, a one-seeded fruit that measures just 0.25 millimetres

The world is full of interesting and delicious fruits. From sour grapes to giant pumpkins, there are around 2,000 different types of fruits growing around the globe. In botanical terms, a fruit is a ripened ovary, a reproductive structure that bears the plant's ovule, also known as the seeds. Once a plant is pollinated, fruits begin to emerge from the fertilised flower and develop, mature and ripen, by which time the encapsulated seeds are ready for dispersal.

When it comes to identifying fruits, there are a whole host of subcategories they fall into. However, they largely sit within one of three categories: simple, aggregate and multiple. Simple fruits include the majority of fruits, such as stone fruits, pome and berries. Their anatomy is typically divided into three parts; the exocarp, mesocarp and endocarp. The outer skin is its exocarp, the mesocarp forms its flesh and the endocarp forms the innermost part of the fruit – the seeds.

Aggregate fruits, on the other hand, are merged from individual flowers that give rise to a curious collection. Raspberries are composed of lots of once-separate carpels – the juicy, seed-containing parts. Then there's the third kind of fruit, which pineapples belong to, called multiple fruits. Unlike aggregate fruits, multiple fruits are formed from a group of flowers that each produce a fruit that matures into a single mass.

Did you know?

A watermelon is 92 per cent water

Plants are proficient in the art of seduction. In lieu of attracting another plant for reproduction, fruits engage the senses of the animals needed for pollination and to spread their seeds. Seed dispersal by way of animal intervention typically occurs in one of two ways. When an animal such as a deer wanders into an orchard and chews down on juicy apples, it feeds not only on the flesh, but the encased seeds as well. From there, the seeds travel through the animal's digestive system and emerge once again among a pile of freshly made droppings. This nutrient-rich manure then provides the conditions needed for the seeds to germinate and a new plant to grow. Other animals, such as many rodent species, bury fruits in an attempt to store them for a later meal. However, when they leave the fruit beneath the soil, the seeds are given the opportunity to germinate and grow.

In the same way the vibrancy of flower petals attracts pollinators, fruits come in all colours of the rainbow in the hope of attracting potential seed-dispersing animals. Studies have shown that mammals such as monkeys and apes disperse more seeds of green fruits, while birds prefer the vibrancy of red fruits. Similarly, smell and taste also act as a way to entice animals to take a bite and spread the seeds within. In Madagascar, several species of colour-blind

© Getty

lemurs play an important role in spreading the seeds of fig trees. As colour isn't an alluring option for these trees, they have evolved fruits that emit a pungent scent when ripe, which the lemurs find enticing.

While many people will be able to sympathise with the lemurs' love of sweet-smelling figs, not all fruits boast such appealing aromas. Pungent odours, including the smells of rotting onions and sewage, are equally important in attracting animals. For example, the noni fruit that's found on Pacific islands and in Southeast Asia, gives off the smell of stinky cheese and rotting fish. However, several bat and bird species aren't at all deterred by the terrible smell, flocking to this foul-smelling feast and subsequently spreading the seeds.

Animals typically access a plant's fruit from the swinging branches of trees and shrubs, but some fruits have begun growing underground. Researchers discovered in 2023 that a new species of palm called *Pinanga subterranea* is growing its fruits and flowers below the surface. Around 171 species of plants are known to grow their fruits underground, including several orchids. Unlike topside fruits, those that are produced by the palm are not exposed to the breadth of pollinators and animals involved in seed dispersal. Scientists believe that subterranean insects may be responsible for pollinating these palms, and wild boar may be the ones to sniff out and dig up the fruit for seed dispersal.

As well as being a vessel for plant propagation, fruits come with a whole host of health benefits for humans to enjoy. From topping up the body's vitamin levels to producing vital fibre needed for a healthy gut, the world's edible fruits are a great source of nutrition, with equally great health benefits. Many fruits such as blueberries, apples and cherries are also high in molecules called antioxidants. Once ingested, antioxidants seek out and destroy harmful molecules called free radicals. Free radicals are naturally produced by the body, as well as exposure to pollution and cigarette smoke, but can contribute to several health conditions, such as the buildup of cholesterol plaque, which leads to the development of heart disease. As well as cardiovascular issues, free radicals have been linked to chronic health problems such as inflammatory diseases and even cancer. When some fruit-sourced antioxidants come into contact with a free radical, they knock off one of its electrons and render it useless, preventing it from causing further harm to the body. To reap all the health benefits that fruits have to offer, the UK's National Health Service recommends eating five 80-gram portions of fruit a day for adults.

Dragon fruit are bright pink in colour but white inside

Did you know?

The heaviest strawberry weighed 289 grams

FINGER LIME

Unlike supermarket limes, the Australian-native finger lime (*Citrus australasica*) erupts with limey caviar when it's squeezed. Found hanging from small finger lime trees in New South Wales, this cylindrical fruit might easily be mistaken for a young cucumber. Inside the fruit are individual sacs of lime juice that surround the central seeds of the plant. Like bubble wrap, the juice sacs help protect the seed pulp when the fruit falls from its tree. The sacs of juice provide a refreshing burst of sourness when you bite into them.

Finger limes have bubbles of juice on the inside

DID YOU KNOW? China is the largest producer of apples, producing more than 44 million tonnes each year

Miracle berries grow on an evergreen shrub native to West Africa

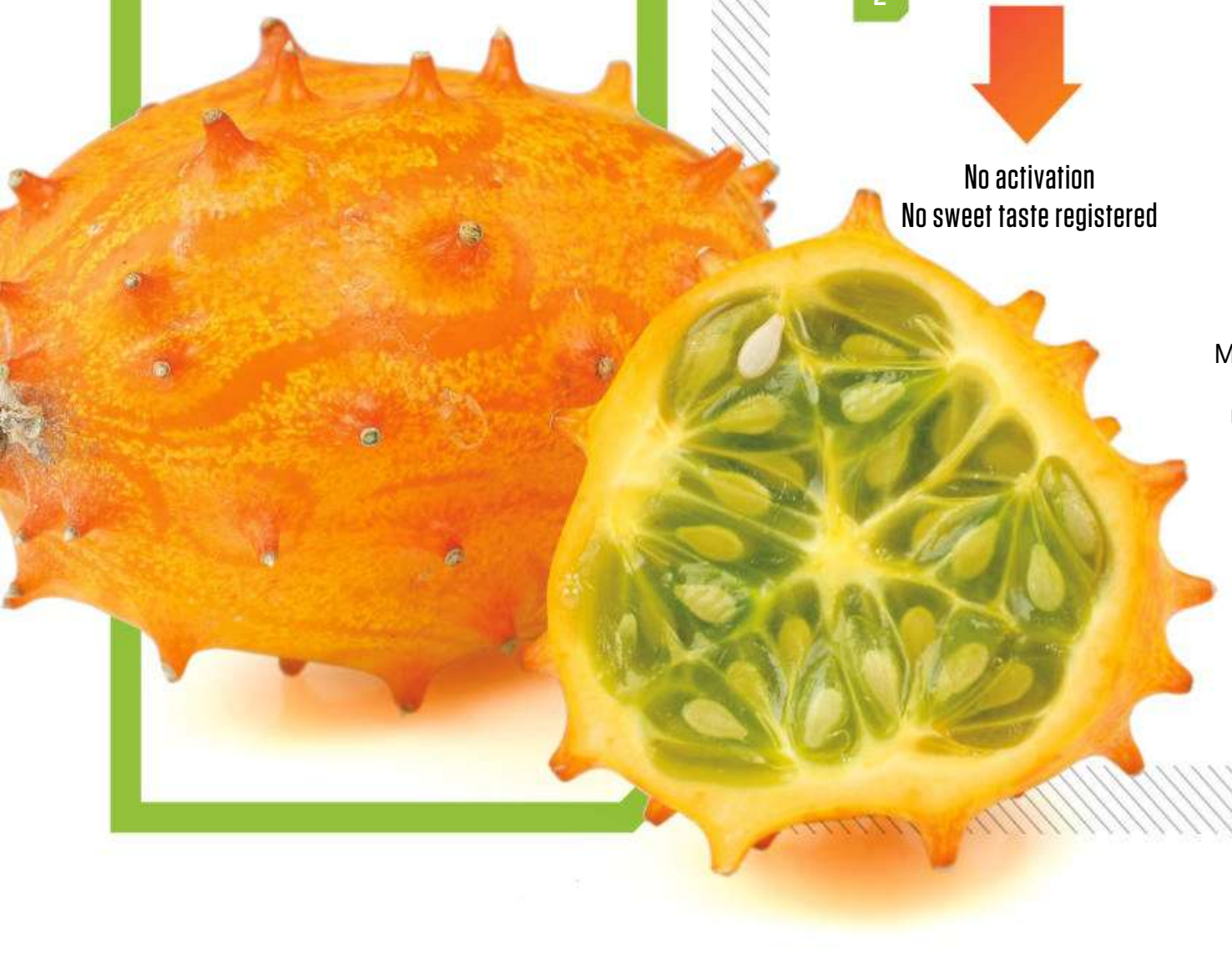
THE MIRACLE FRUIT

Miracle berries (*Synsepalum dulcificum*) are native to the tropical regions of West Africa but have been cultivated around the world for their miraculous abilities. Despite being tasteless, miracle berries possess a protein that transforms the taste of other acidic or bitter foods. After chowing down on these berries, they will make taking a bite out of a lemon taste like you're drinking the sweetest lemonade and make a swig of apple cider vinegar bearable.

The mysterious powers of the fruit come from a natural sweetener called miraculin. When ingested, miraculin binds to the sweet taste receptors on the tongue for up to around 60 minutes. When a bitter-tasting food comes into contact with the miraculin, it changes shape, causing the sweet receptor to think it's come across a molecule from a sweet-tasting substance such as sucralose or aspartame. Even though miracle berries might make a great sugar or artificial sweetener substitute, the fruits are only produced on a small scale and are not able to replace what's currently commercially available.

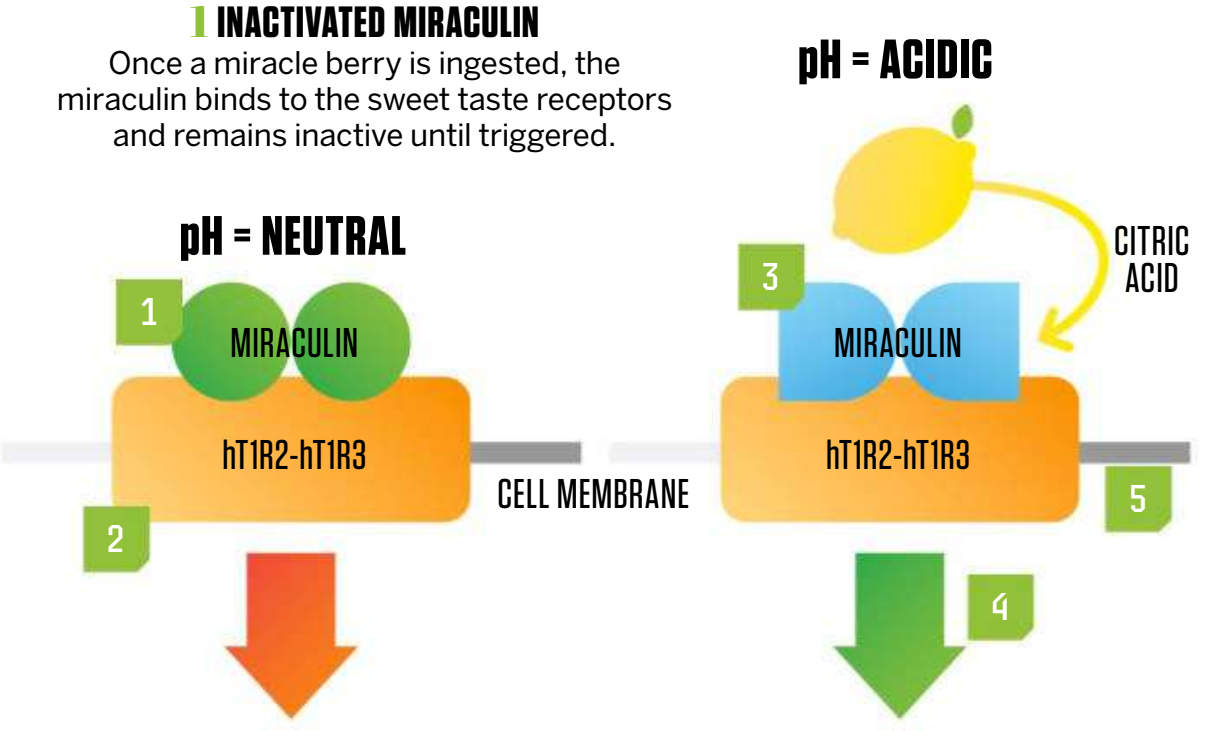
HORNED MELON

Kiwano (*Cucumis metuliferus*), also known as the African horned cucumber or horned melon, is an intimidating fruit that originated in the Kalahari Desert, Africa, but has been cultivated in the tropical regions of South Africa and other parts of the world, such as New Zealand. The contrasting colours of the fruit's outer orange skin and its vibrant green pulp entice a myriad of critters, including birds, primates, rodents and antelopes, to feast and spread its seeds. The pulp is said to taste like a cross between a banana, melon and lime, and is packed with vitamins B and C.



A SWEET MIRACLE

How miraculin deceives your taste buds



1 INACTIVATED MIRACULIN
Once a miracle berry is ingested, the miraculin binds to the sweet taste receptors and remains inactive until triggered.

No activation
No sweet taste registered

Activation
Sweet taste registered

2 SWEET RECEPTORS
Miraculin binds to a particular receptor called hT1R2-hT1R3.

3 ACID ACTIVATION
With acids, such as the citric acid within a lemon, the miraculin changes shape and activates the sweet taste receptor.

4 A SWEET TASTE
The sweet receptor that's bound to the miraculin registers a sweet taste, rather than an acidic one.

5 CELL MEMBRANE
Sweet taste receptors can be embedded in the cell membranes of the taste buds, called papillae.

© Alamy / Getty

5 FACTS FRUITS THAT SMELL

1 JACKFRUIT (*ARTOCARPUS HETEROPHYLLUS*)
Found in tropical and subtropical parts of the world, the jackfruit has a rotten-onion scent, but with a pleasant hint of pineapple and banana.

2 CEMPEDAK (*ARTOCARPUS INTEGER*)
As with many fruits, the smell they emit intensifies the riper they get. For cempedak fruit, an already-potent aroma turns to the smell of ammonia when overripe.

3 WOOD-APPLE (*LIMONIA ACIDISSIMA*)
In the forests of Southern India you might find the interesting aroma of wood-apples, which has been described as a combination of fruity raisins and blue cheese.

4 MARANG (*ARTOCARPUS ODORATISSIMUS*)
The presence of a marang fruit will quickly fill a room with an odour reminiscent of gasoline, despite having a fruity pear-and-pineapple taste.

5 PEDALAI (*ARTOCARPUS SERICICARPUS*)
Found in Borneo and the Philippines, this melt-in-your-mouth fruit grows with an unusual hair-like husk and bears a scent resembling meringue.

SNAKE FRUIT

As its name suggests, snake fruit (*Salacca zalacca*) has a unique surface, akin to that of king cobra scales. The unusual fruit is grown in Southeast Asia and is native to Indonesia. Unlike many other drupes, the snake fruit has a leathery peel that's made up of lots of small, triangular scales. When the scales are chipped away, three lobes of juicy, white flesh are revealed. Snake fruit tastes like a combination of apple and pineapple, with the crisp texture of an apple, and is often eaten raw or turned into jams or syrups.

Did you know?

Humans and bananas share 50 per cent of their DNA

The Southeast Asian rambutan is a relative of the lychee

BUDDHA'S HAND CITRON

A popular fruit within Asia, Buddha's hand citron (*Citrus medica digitata*) is thought to have reached China in the satchels of Buddhist monks travelling from India in the 4th century. Other than its digit-like appearance, one of the remarkable things about this fruit is its high level of pith. Citruses, such as lemons and limes, all have an internal fibrous pith to support juicy seed-bearing centres. However, the majority of this fruit is made up of pith, which limits its use. Traditionally, Buddha's hand is used to enhance the scents of other foods, such as sugars and ice cream, thanks to its potent tangerine-and-lemon aroma.

The fruit is sometimes used as a religious offering

DID YOU KNOW? The double coconut (*Lodoicea maldivica*) grows the world's largest seed, which weighs around 25 kilograms

THE KING OF ALL FRUITS

Rotting onions, old socks, bin juice and raw sewage are all ways in which the smell of the durian fruit (*Durio zibethinus*) has been described. The smell of durian is so potent that consumption of the fruit has been banned on public transport in Singapore, and in some hotels in Thailand. A durian's scent stems from its ripened pulp and is the result of the release of a combination of more than 50 compounds, including an odorous sulphur-smelling chemical called ethanethiol. On their own the individual compounds aren't particularly powerful in their odours, nor does any smell like a durian. However, when they all come together they create the symphony of durian smell. The reason behind the odorous nature of this fruit is like any other: to entice animals that find the scent appealing in the hope of dispersing the seeds within.

Despite its pungent aroma, durian, also nicknamed the 'king of fruits', is an incredibly popular food, particularly in many Southeast Asian countries. As a nutritious fruit, durian is packed with helpful vitamins and minerals that support the body's immune system. Studies have also shown that the fruit is full of folate and folic acid, which can help combat anaemia and promote regular tissue growth during pregnancy. From coffee to candy, the distinctive scent and taste of durian fruit has also found its way into countless snacks and confectionery around the world.

DURIAN ANATOMY

Where does its infamous odour come from?

Although it might smell strong, ripe durian has a sweet, caramel taste and a custardy texture

CHOCOLATE PUDDING

While hanging from its parent plant, the black sapote (*Diospyros nigra*), also known as the chocolate pudding fruit, resembles an unripened tomato. However, give it time to ripen and it transforms into a delicious dessert. After ten days of picking the chocolate pudding fruit and storing it at room temperature, the flesh within will turn a rich, gooey brown and gain a sweet, pudding-like flavour, with a hint of banana. Black sapote is full of nutrients, including around four times the amount of vitamin C found in an orange.

Black sapote tastes like a dessert when it's ripe

© Alamy / Getty / Shutterstock

INVASIVE SPECIES UNCOVERED

Some species are able to thrive in areas far beyond their natural range. How do they spread, and how do they threaten our planet's diversity?

WORDS **ALEX DALE**

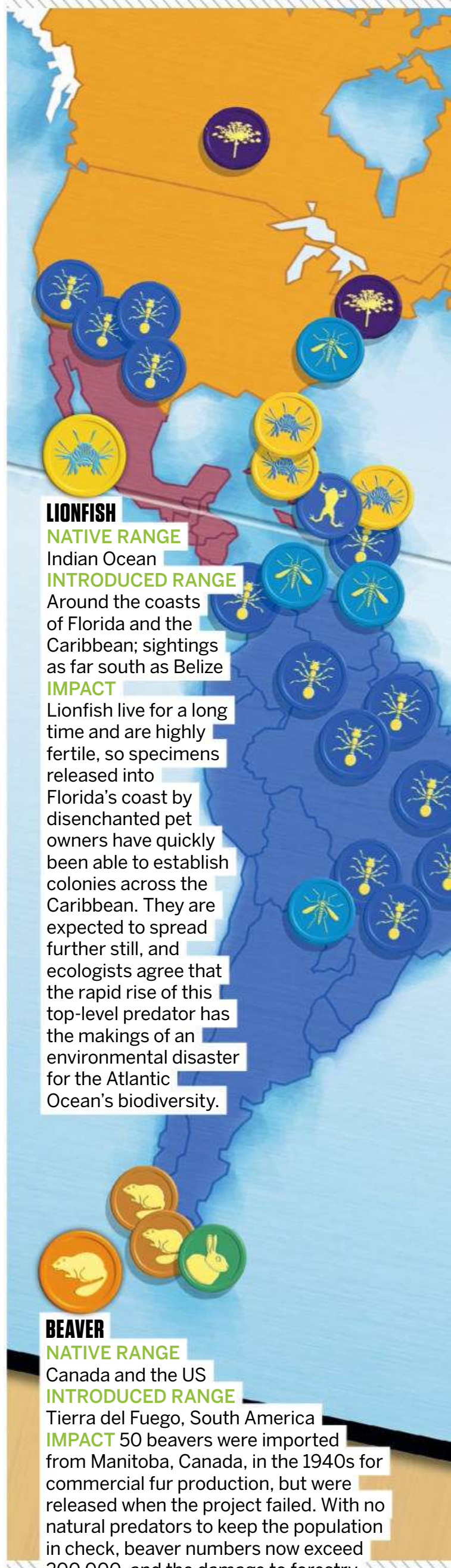
Tibbles was a tabby cat with blood on his claws. As the legend goes, he was the feline companion of a lonely lighthouse keeper posted at Stephens Island, a remote rock off the New Zealand coast. Not long after their arrival in 1894, Tibbles the cat started to bring his owner gifts: the remains of small birds not yet known to science. By the time naturalists could review the bodies and confirm that the Stephens Island wren was indeed a brand-new species, Tibbles had already wiped them all out.

Like so many good yarns, Tibbles' tale is likely to be apocryphal. But what is suspected is that the Stephens Island wren was once widespread throughout mainland New Zealand. It was a nocturnal flightless bird that had evolved in an ecosystem without land predators. Its fortunes changed when the Māori people migrated to the islands from Polynesia in the late 13th century. Stowaway rats on boats soon established themselves in their new surroundings and rapidly picked off the ill-prepared indigenous wildlife. Tibbles and his fellow cats merely delivered the final blow to a struggling island population.

However you wish to interpret Tibbles' tale, it illustrates how the arrival of a new species into an established ecosystem can be devastating. Species don't evolve in splendid isolation – they do so in tandem with the flora and fauna around them, making adaptations that enable them to be competitive in their surroundings. Species adapted to survive in tough ecosystems can flourish in softer surroundings, and their actions can have a knock-on effect that influences the entire food chain, from top to bottom.

But why are some species more adaptable than others? "This is a tricky question for evolutionary theory, because natural selection can't equip species for future challenges," says Dr Stuart Reynolds, professor emeritus of biology at the University of Bath. "One area where we are beginning to get a handle on this is the tolerance of invasive species to diseases." One well-known example of this is grey squirrels in Europe, which are tolerant to a disease that's deadly to the native red squirrel, allowing the grey squirrel to dominate. A similar process sees Harlequin ladybirds from Asia outlasting native European ladybirds, and Reynolds raises the possibility that these species may have evolved the energy-costly ability to keep diseases alive in their bloodstream. Reynolds hypothesises that this is a kind of 'biological weapon', enabling them to infect other species and gain an edge over their competition.

Adaptable and aggressive, invasive species continue to expand their territory to this day, assisted by factors such as climate change and increasing volumes of world trade. These are factors caused by the most invasive species on this planet – not Tibbles the cat, but humans.



LIONFISH

NATIVE RANGE
Indian Ocean

INTRODUCED RANGE
Around the coasts of Florida and the Caribbean; sightings as far south as Belize

IMPACT
Lionfish live for a long time and are highly fertile, so specimens released into Florida's coast by disenchanted pet owners have quickly been able to establish colonies across the Caribbean. They are expected to spread further still, and ecologists agree that the rapid rise of this top-level predator has the makings of an environmental disaster for the Atlantic Ocean's biodiversity.

BEAVER

NATIVE RANGE
Canada and the US

INTRODUCED RANGE
Tierra del Fuego, South America

IMPACT 50 beavers were imported from Manitoba, Canada, in the 1940s for commercial fur production, but were released when the project failed. With no natural predators to keep the population in check, beaver numbers now exceed 200,000, and the damage to forestry has been huge.

DID YOU KNOW? Lionfish breed very quickly – a single female can spawn up to 2 million eggs a year

HOSTILE TAKEOVER

Invasive species threaten biodiversity across the planet. Learn about the factors that make these species unwelcome guests in their new homes

CHINESE MITTEN CRAB

NATIVE RANGE Korean and Chinese coastlines
INTRODUCED RANGE Temperate European waters from Scandinavia as far south as Portugal, small pockets in the US
IMPACT Mitten crabs, imported via ballast water, are aggressive omnivores who outcompete native marine life for algae. They also burrow into banks, resulting in damage and soil erosion.

GIANT HOGWEED

NATIVE RANGE Georgia, Western Asia
INTRODUCED RANGE Throughout Europe and North America
IMPACT Outcompetes native plants by shading them from the Sun. This has a knock-on effect on invertebrates, who rely on the vanquished plants to survive. The sap causes painful blisters when it comes in contact with human skin.

RED IMPORTED FIRE ANT

NATIVE RANGE Brazil and Argentina
INTRODUCED RANGE Widespread throughout the Southern US and Queensland, Australia
IMPACT They damage crops and attack newborn livestock and poultry. The aggressive foragers can short-circuit electrical components and are capable of delivering painful bites to humans.

CANE TOAD

NATIVE RANGE Central and South America
INTRODUCED RANGE Australia, Caribbean, Florida, Philippines
IMPACT This highly toxic toad multiplies rapidly and its poisonous glands kill predators, meaning their growth continues unchecked. Cane toads compete with native animals for shelter. In Australia, one-third of rainbow bee-eater nest burrows are destroyed by cane toads.

RABBIT

NATIVE RANGE Europe
INTRODUCED RANGE South America, Australasia
IMPACT Australia's biggest killer is the unassuming rabbit. They were introduced in the 19th century for game and have run amok, consuming crops with ferocity and leading to the extinction of numerous indigenous species. Their grazing leaves topsoil open to the elements, causing soil erosion that will take hundreds of years to regenerate.

INVASIVE SPECIES BY NUMBERS

TEN NEW SPECIES

are established in Europe each year

1.7 MILLION

The number of acres per year invasive species advance across the US in all directions. It's an area that's two-thirds bigger than the state of Delaware

650 INVASIVE SPECIES

have been found in US marine parks

1 INTRODUCED

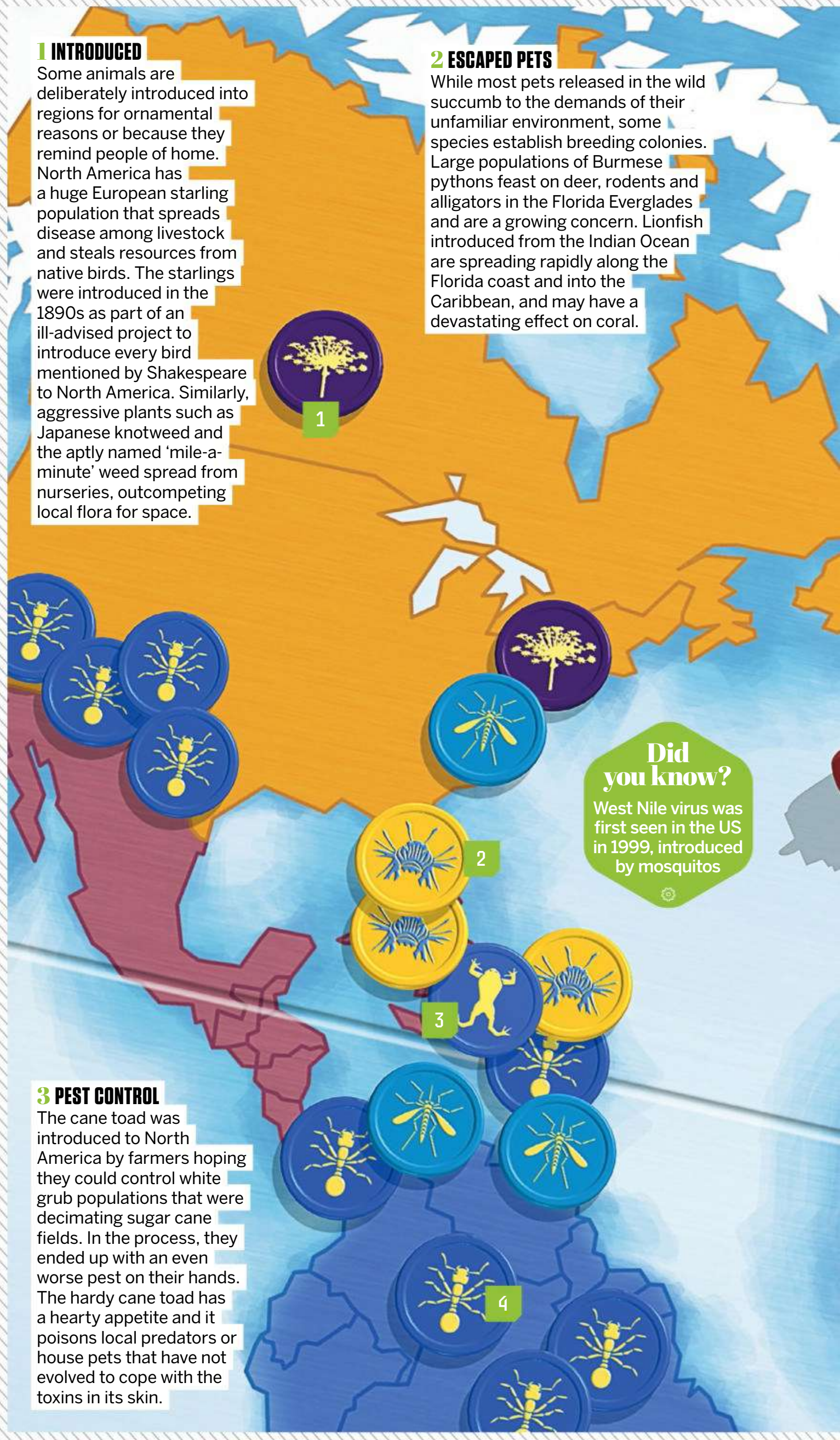
Some animals are deliberately introduced into regions for ornamental reasons or because they remind people of home. North America has a huge European starling population that spreads disease among livestock and steals resources from native birds. The starlings were introduced in the 1890s as part of an ill-advised project to introduce every bird mentioned by Shakespeare to North America. Similarly, aggressive plants such as Japanese knotweed and the aptly named 'mile-a-minute' weed spread from nurseries, outcompeting local flora for space.

2 ESCAPED PETS

While most pets released in the wild succumb to the demands of their unfamiliar environment, some species establish breeding colonies. Large populations of Burmese pythons feast on deer, rodents and alligators in the Florida Everglades and are a growing concern. Lionfish introduced from the Indian Ocean are spreading rapidly along the Florida coast and into the Caribbean, and may have a devastating effect on coral.

3 PEST CONTROL

The cane toad was introduced to North America by farmers hoping they could control white grub populations that were decimating sugar cane fields. In the process, they ended up with an even worse pest on their hands. The hardy cane toad has a hearty appetite and it poisons local predators or house pets that have not evolved to cope with the toxins in its skin.



Did you know?

West Nile virus was first seen in the US in 1999, introduced by mosquitos

DID YOU KNOW? In 2007, a cane toad the size of a dog was found in Australia. He weighted 861 grams and was 20 centimetres tall

HOW ALIEN INVADERS SPREAD TO NEW LOCATIONS

Opportunistic species are being given the chance to move around the globe and set up in new locations. Either directly or indirectly, human activity is usually to blame...

4 CLIMATE CHANGE
Species adapted to warmer climates are increasing their range as Earth's temperature rises. Invading crabs, for instance, are posing a dire threat to Antarctica's marine life, who have no defence against their claws. Climate change also exacerbates the spread of species brought to new regions by other means. For example, fire ants that arrived in Alabama from Brazil can now be found across Southern US.

5 TRANSPORT
Many animals stow away on ships and redistribute themselves when they arrive at their destination. The international tyre trade is to blame for the rise of the Asian tiger mosquito. Truck tyres provide the perfect conditions for mosquitos to lay their eggs, and the pests can now be found on every continent on Earth bar Antarctica.

100% RABBITS
98.9% OPOSSUMS
99.3% RACCOONS
87.5% BOBCATS

The decline in mammals in the Florida Everglades, from 2003 to 2011 due to the proliferation of the Burmese python

150 MILLION

European starlings are now living in the US, spread from just 60 released into Central Park in 1890

20 PER CENT

of recorded animal extinctions are solely down to invasive species, including:

56% OF AMPHIBIAN SPECIES
30% OF MAMMAL SPECIES
25% OF REPTILE SPECIES
AND 13% OF BIRD SPECIES

© Flying Chilli Ltd

SCIENCE

DARKROOM PHOTO-DEVELOPING SECRETS

Step into a darkroom and discover how film is transformed into photographs

WORDS SCOTT DUTFIELD

DID YOU KNOW? The earliest descriptions of a 'camera' are in Chinese manuscripts from 400 BCE

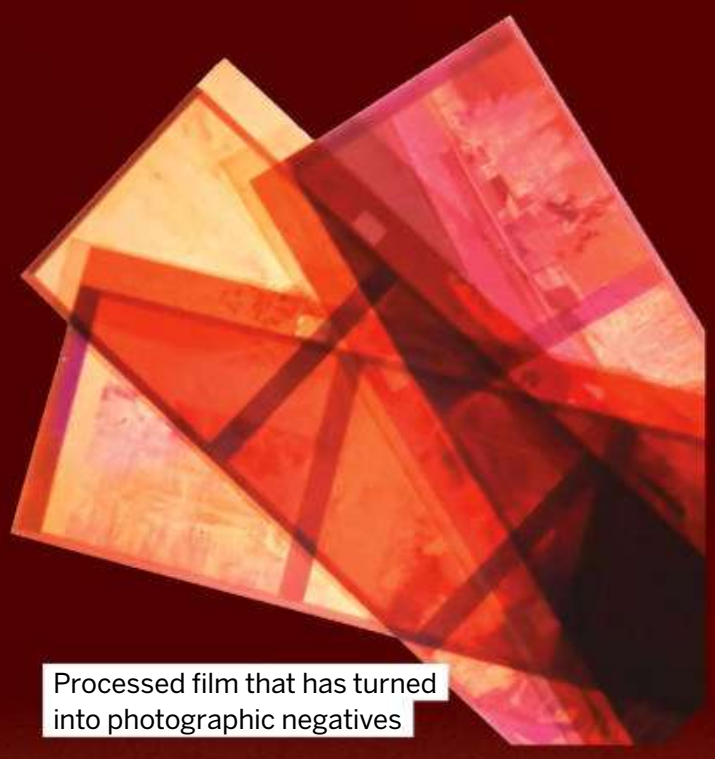
The science of photographic film developing works similarly to how our eyes see and process images. Our ability to see comes from the interaction of our eyes with tiny particles of light called photons. When light is emitted, photons bounce off the objects around us, head into our eyes and onto photoreceptor cells. These cells send signals to the brain, which then builds an image of what we've seen. The developing of photographic film begins the instant a photo is taken. When a camera's shutter 'eyelid' opens, light is temporarily allowed to enter the camera through the lens and hit the photosensitive film. The light leaves an imprint on the film that can be interpreted and printed by a photographer in a darkroom.

Photographic film has been in use since the early 1800s, when French painter Louis Daguerre created a process that used liquid iodine and a copper plate to create the first photographs. Since the modern era of film photography, a material called cellulose acetate has been used, which is derived from wood pulp and acid. To give the cellulose acetate its photosensitive abilities, it's coated with a photographic emulsion that contains silver and gelatin. Like the chocolate chips suspended in cookie dough, microscopic crystals of silver halide are imprisoned in a gelatin insulator. This coating is what gives film its photographic qualities. When the crystals are exposed to photons of light, their structure changes as they obtain energy from photons. The changes in the crystals' structure are what you see in photo film. When an object, such as a tree, bounces photons through the camera lens, its impression is captured on the film in the form of affected crystals. This is typically how black-and-white photos are produced. Colour film applies the same principles, but uses different layers of silver halides that are sensitive to different wavelengths of light, such as blue, green and red.

Did you know?
The first human subject was photographed in 1838

Before a roll of film can reveal its photos, it needs to be prepared for life in the light. Through a series of chemical interactions, the film is put through a process of light stabilisation. This prevents any of those tiny silver halides from reacting with photons and altering the images on the film, as well as

"The light leaves an imprint on the film that can be interpreted"



Processed film that has turned into photographic negatives

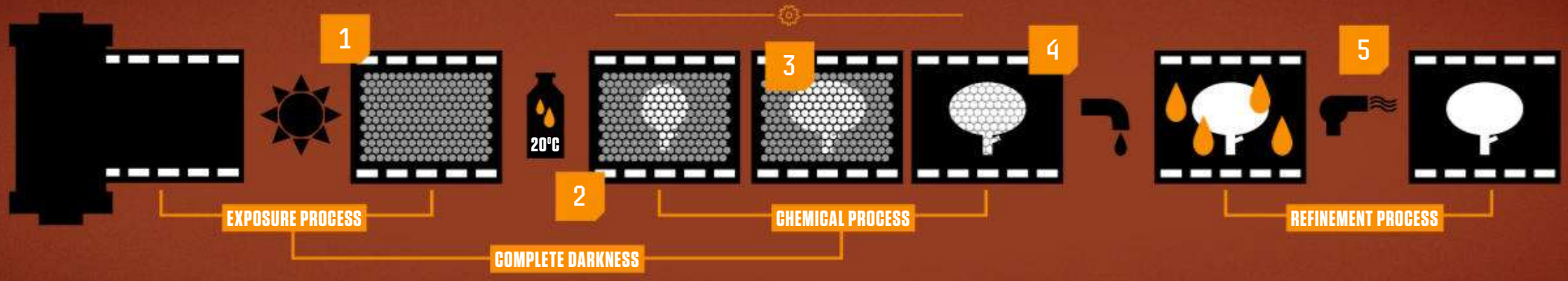
FIRST FILM ROLL

In 1881, photography pioneer George Eastman formed the Eastman Dry Plate Company. From this venture came a host of innovations in both photography and motion pictures. One advancement was the invention of flexible dry film roll, made with silver bromide and gelatin emulsion-coated paper. What was so impressive about Eastman's film roll was that it allowed the photographer to take one photograph after another. Until that point, photographs were produced individually. In May 1888, Eastman released the first box camera, called the Kodak, which came with a preloaded roll of film long enough for 100 exposures. The Kodak was the beginning of amateur photography, a practice that had previously been limited to professionals.

George Eastman was the founder of what became the Eastman Kodak Company

MAKING NEGATIVES

How to turn film into light-tolerant negatives



1 EXPOSURE
Unprocessed film will capture all the light that it's exposed to using tiny silver halide crystals.

2 RINSING
The exposed film is kept in complete darkness inside a developing canister and then rinsed with water with a temperature of around 20 degrees Celsius.

3 DEVELOPMENT
A chemical developer is poured into the container, transforming the silver halide into solid silver. A stop bath solution, typically acetic acid, is then added to neutralise the developer.

4 FIXING
The film is exposed to a fixing solution that removes any unusual silver halide. A fixer bath is then used to neutralise the fixer.

5 WASH AND DRY
The film is washed with water to remove any leftover solution and is hung up to dry.

© Getty / Alamy

A series of developer and fixer chemicals are used to stabilise photographs

BEHIND THE CURTAIN

What equipment is used inside a darkroom?

fixing in place the silver that's already reacted to the light. Once the silver halides have been tamed, the film, which is referred to as a negative at this point, is ready to enter the darkroom to develop photographs. Negative film is most common in still photography. However, there's another type known as slide or reversal film. When an image is taken using negative film, the image is inverted, but slide film captures images as you would see them in real life. Once processed, these film types will have a transparent base, which means they can be used in slide projectors.

For as long as film photography has been around, so has the darkroom. As the name suggests, these photographic dens are free from natural light while in use, glowing with a scarlet hue to prevent photosensitive paper from prematurely developing. The infiltration of sunlight, or indeed artificial white light, can trigger untreated photographic paper and erase any images it holds.

Much like film, photographic paper is made from a base layer, either paper or plastic, which is coated in a silver-gelatin emulsion. To transfer the image from the film onto the paper, a projector-like device called an enlarger passes light through the film negative and onto a sheet of photographic paper. The image and its colours imprint onto the paper, which can then be developed and fixed in the same way as the original film.

Did you know?

The longest film negative measures 79.37 metres

1 RED LIGHTS

Without natural light, photographers need to use something to see what they are doing during development. Red or amber lights are used because they don't produce wavelengths that affect photosensitive paper. However, some types of paper are so sensitive that they have to be worked on under ultraviolet light to keep them safe.

2 ENLARGER

The images captured on film negatives are placed inside an enlarger, where they are focused and the desired magnification is set. A beam of light is then passed through the negative, projecting the image directly onto photographic paper. The longer the paper is exposed to the light, the darker the image will appear, so getting the timing right is crucial.

3 FOCUS FINDER

This nifty device works alongside the enlarger and helps keep photographs in focus. Before the paper is used, the image is first projected onto a base plate using the enlarger. A focus finder is then placed onto it. Like a microscope, it's used to spot where the image might be out of focus. The photographer can then adjust the enlarger ready for the photo paper.

DID YOU KNOW? The largest single photographic print, called the Great Picture, measures 325.44 square metres

6 DIVIDED SPACE

Darkrooms are typically divided into two halves: a wet side and dry side. All the chemicals used to develop and wash the photographs are kept and used on the wet side, while electrical equipment, such as the enlarger, is kept on the dry side.

5 DRYING RACKS

Darkrooms are often equipped with either drying racks or lines, from which freshly developed photographs hang. Once the process of development is complete, the photographs are thoroughly washed and left to dry for several hours.

4 DEVELOPMENT AND FIXING

Once an image has been projected onto the photographic paper by the enlarger, the paper needs to go through a process of development and fixing, similar to the process that turns film into negatives. The photograph is dipped through a series of chemical developers, fixers and stop baths to develop the image and prevent the paper from experiencing further light exposure.

A film photographer bringing photos to life

© Getty / Illustration by Nicholas Forder

DO VITAMIN PILLS WORK?

Our bodies require a crucial balance of vitamins and minerals - but not all supplements help

WORDS AILSA HARVEY

As we better understand the micro and macro nutrient requirements of our bodies, it can make us question whether we are getting everything we need through our meal choices alone. Many of us opt to take a daily vitamin tablet to help get the right balance. Specific vitamin supplements can be a vital addition to someone's diet if they are suffering from a deficiency. Some of the most common deficiencies include a lack of vitamin D, due to a minimal selection of foods containing enough of it; iron deficiency, which can be caused by heavy menstrual periods, and vitamin B12, which keeps your nerve cells signalling efficiently.

Just because you're swallowing a measured dose of a vitamin doesn't mean that it is all being absorbed. To make sure your vitamin pills are doing their job, you need to research the absorption requirements of each specific vitamin. Oftentimes, vitamin pills contain conflicting ingredients. For example, if you are taking a multivitamin containing both magnesium and calcium, the magnesium can prevent the body from absorbing much of the calcium.

Did You Know?

Before 1912, only three essential nutrients were known

Similarly, the foods and beverages you consume at the same time as taking a vitamin pill can impede the body's uptake. For example, you should avoid drinking coffee and tea when taking an iron tablet, as the tannins in these products reduce how much iron you absorb. While there are vitamin tablets that can improve almost all bodily functions, it's essential to understand their ingredients to make the best use of them.

ALL IN ONE

Multivitamins appear to provide all your essential vitamins in one tablet, and nearly half of UK adults choose to take these daily. But these tablets should not be used to replace a well-balanced diet, as vitamins and minerals are more easily absorbed from foods, and whole foods contain other important nutrients such as fibre. Your body can only absorb so much of each vitamin. If you take multivitamins but also have a fairly balanced diet, it's likely that many of the vitamins you purchase aren't needed and pass straight through your body. Taking too much of some vitamins, such as vitamin A and iron, can be detrimental to your health.

Multivitamins come as chewable gummies, tablets, powders and liquids

BODY BENEFITS

The parts of the body that each vitamin and mineral help the most

1 VITAMIN A
Vitamin A can be stored in the body for later use, so isn't essential in daily tablets.

2 VITAMIN B1
This is also called thiamine. Too much sugar, caffeine and alcohol can cause a B1 deficiency.

3 VITAMIN B2
When taken as a tablet, B2 is best absorbed between meals.

4 VITAMIN B5.
Some people with high cholesterol take B5 tablets.

5 VITAMIN B6
Maintains levels of certain proteins in the brain. B6 is prescribed to patients who suffer from seizures.

6 VITAMIN B9
Also called folic acid, B9 produces genetic material and impacts mental health.

7 VITAMIN C
Taking vitamin C with iron tablets helps more iron to be absorbed.

8 VITAMIN D
People often take vitamin D supplements to protect against the bone-weakening disease osteoporosis.

9 VITAMIN E
Premature babies often need more of this powerful antioxidant.

10 CALCIUM
This is the most abundant mineral in the body. Those with brittle bones may need extra calcium.

11 COPPER
Copper is essential throughout the body, but taking too much of it can cause liver damage.

12 IRON
This mineral is used to make the protein in red blood cells. People with anaemia use iron supplements to reduce fatigue.

13 IODINE
Iodine is responsible for making thyroid hormones and controlling your metabolism.

14 POTASSIUM
Our cells maintain consistent levels of fluid thanks to this mineral. You should never take this mineral without a prescription, as too much of it slows your heart.

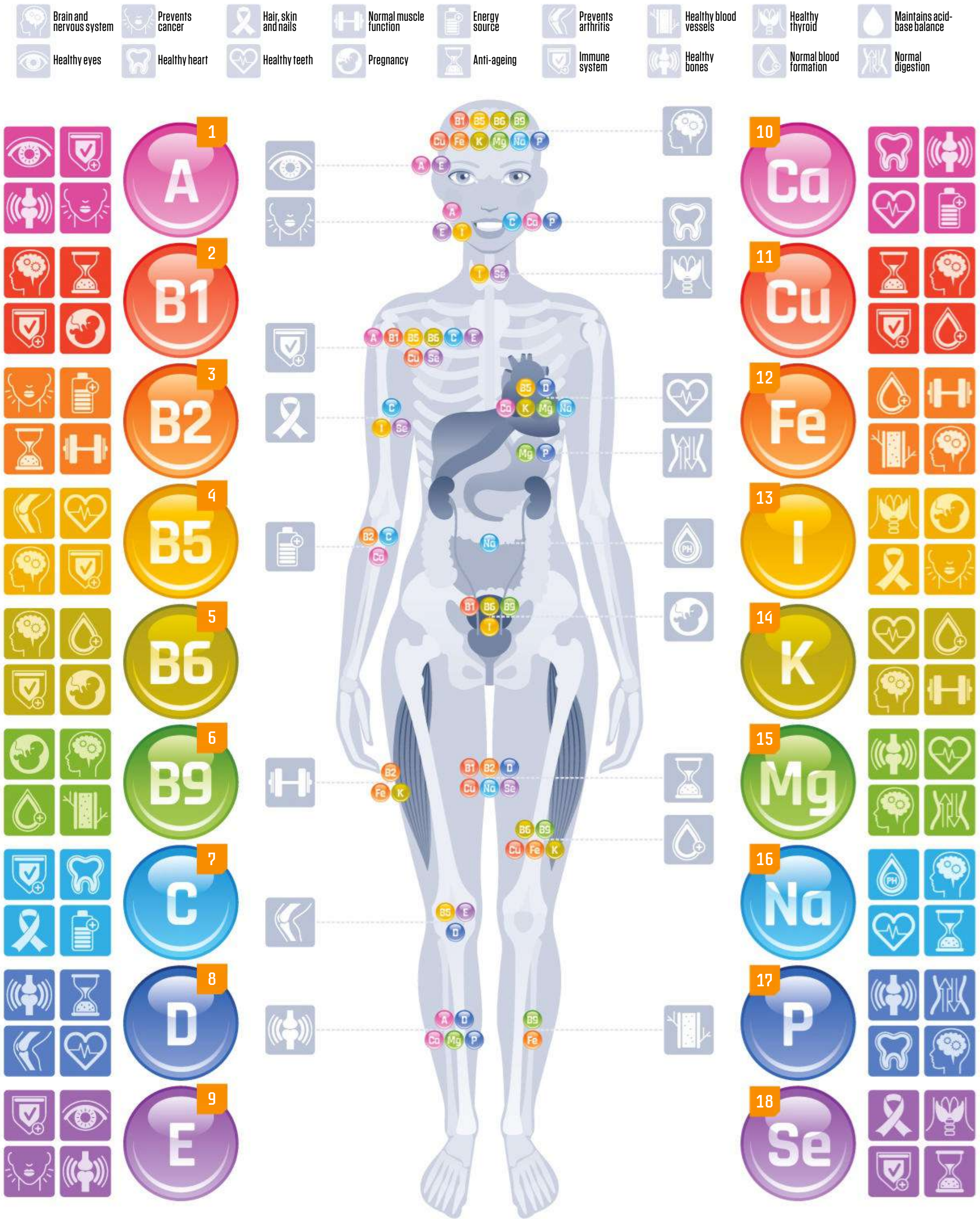
15 MAGNESIUM
Magnesium keeps blood sugar and blood pressure at healthy levels. Doctors sometimes prescribe this supplement to those with type 2 diabetes.

16 SODIUM
Nerve impulses that allow your muscles to contract are controlled by sodium, as well as the balance of water and other minerals.

17 PHOSPHORUS
Alongside calcium, phosphorus helps build strong bones. This supplement can be used to prevent kidney stones.

18 SELENIUM
Enough of this mineral protects against cell damage. People with HIV and other health conditions might need supplements.

DID YOU KNOW? Lack of iron is the most common nutritional deficiency in the world



© Getty / Shutterstock

Around 500,000 new Alzheimer's cases are diagnosed each year

ALZHEIMER'S DISEASE EXPLAINED

How this degenerative disease gradually shrinks brain cells and how it's treated today

WORDS SCOTT DUTFIELD

Alzheimer's disease is the most common form of dementia, a degenerative disease that leads to the loss of cognitive function, such as memory or critical thinking. It's estimated that at least 55 million people around the world are living with Alzheimer's disease or another form of dementia. Scientists have discovered that two proteins are involved in the development of Alzheimer's, called amyloid and tau.

In a healthy brain, amyloid proteins are broken down and removed by enzymes. However, for someone with Alzheimer's, these proteins are allowed to build up and form clumps called plaques. Amyloid plaques can then lodge themselves between brain cells called neurons and inhibit or disrupt their function. Tau proteins, on the other hand, group together in what's called a 'neurofibrillary tangle' within neurons.

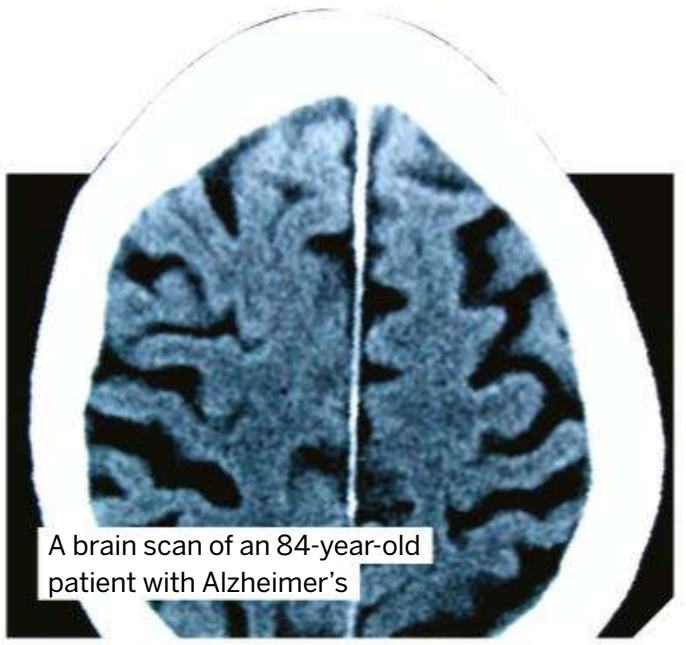
Within a healthy neuron, tau binds to structures called microtubules, which have the job of transporting nutrients around the cell for physical support. However, within a brain afflicted with Alzheimer's disease, tau detaches from the microtubules, bunches together and forms long threads. These tangles of tau then block signals transmitted through neurons and halt communication within certain parts of the brain.

Initially, Alzheimer's disease affects the memory portions of the brain, such as the hippocampus, then progresses through the cerebral cortex to disrupt language, reasoning and social behaviour. Over time, as neurons are continually damaged and destroyed by the disease, the brain begins to die away and lose its volume, known as brain atrophy.

As to why amyloid and tau misbehave and what the triggers are for dementia to develop, scientists aren't entirely sure. Genetics plays a key role in its development, but there is no single gene responsible. A combination of the more than 70 genetic regions within human DNA is associated with Alzheimer's disease. Environmental factors such as increased levels of aluminium and exposure to viruses and food toxins have been linked to the disease.

Did you know?

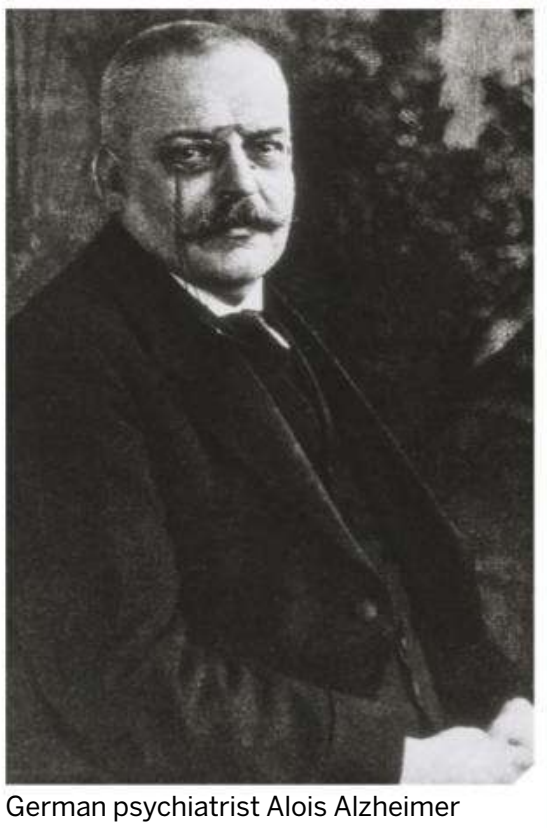
The youngest person diagnosed with Alzheimer's was 19 years old



A brain scan of an 84-year-old patient with Alzheimer's

THE MAN WHO'S BEHIND THE NAME

German neuroanatomist Alois Alzheimer was first to describe the condition that would later bear his name. In 1906, Alzheimer first described "a peculiar severe disease process of the cerebral cortex" after studying the brain of a 50-year-old female patient who suffered from several mental health issues, including paranoia, confusion and memory loss, during the last five years of her life. Following the woman's autopsy, Alzheimer examined the patient's brain matter and discovered clumps of plaque and fibrous tangles, which he attributed to be the cause of the patient's impaired cognitive function. The cerebral cortex of her brain was also thinner than a healthy brain's. Alzheimer's work went largely unnoticed until 1910, when fellow German psychiatrist Emil Kraepelin named the disease in the eighth edition of the *Handbook of Psychiatry*.

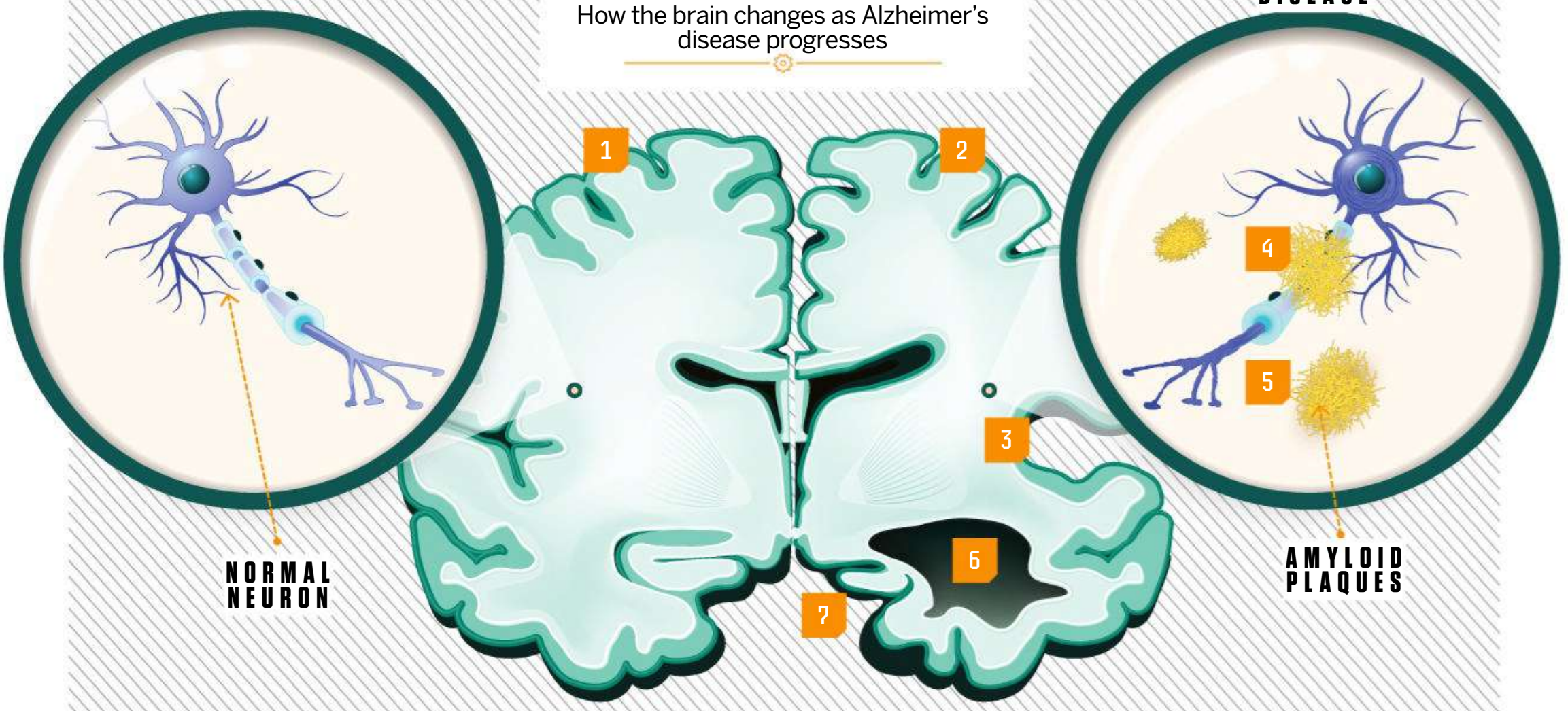


German psychiatrist Alois Alzheimer

DID YOU KNOW? The risk of developing Alzheimer's at age 45 is one in five for women and one in ten for men

DEGENERATION

How the brain changes as Alzheimer's disease progresses



1 HEALTHY BRAIN
This is how a typically healthy brain and neurons appear, with tight folds called gyri.

2 CEREBRAL CORTEX
The outermost layer of the brain shrinks over time. The cerebral cortex is responsible for processing memory, language and learning.

3 SULCAL WIDENING
As part of the shrinking process, the grooves or depressions in the brain, called sulci, widen.

4 AMYLOID PLAQUE
Clusters of amyloid proteins form plaques, which bind to brain cells and disrupt their ability to function, ultimately leading to their death.

5 TAU DAMAGE
Bundles of tau proteins form within the cell, damaging the cell and halting communication between it and other parts of the brain.

6 ENLARGEMENT
Ventricles that carry cerebrospinal fluid become enlarged. The rate of enlargement has been used to measure Alzheimer's progression.

7 HIPPOCAMPUS
Short-term memory is affected when the brain cells of the hippocampus degenerate and the region begins to shrink.

DRUGS IN DEVELOPMENT

At present, there's no cure for Alzheimer's disease. However, there are several treatments and medicines designed to slow its progression. One promising weapon against Alzheimer's currently in development is called donanemab. In July 2023, researchers released the results from the third phase trial of donanemab. The researchers found that the drug slowed a decline in memory by 35 per cent in study participants who had early onset Alzheimer's. However, donanemab wasn't effective among patients with Alzheimer's in its later stages, where tau protein levels were high. Donanemab works by teaching the body's immune cells to attack and remove amyloid plaques that have built up in the brain. The study found that three-quarters of people on the drug had amyloid cleared from their brains by the end of the trial. Donanemab is not yet available for use in the UK, and will be subject to evaluation from regulatory boards and the National Institute of Health and Care Excellence (NICE) over the next few years.

Donanemab is administered intravenously, directly into the veins

© Getty / Shutterstock

HOW HENNA STAINS SKIN

This dye, made from leaves, is used all over the world

WORDS SCOTT DUTFIELD

The henna tree can be found across Asia and in the northern regions of Africa and Australia

Henna is a type of dye that's derived from the leaves of the henna tree. When left on the skin, henna paste temporarily stains the skin a reddish-orange colour. It's used around the world to decorate the skin with intricate patterns and body art, known as mehndi, for celebrations such as weddings and birthdays.

Unprocessed, the leaves of the henna tree won't transfer a dye. To produce the dye, the dried leaves must first be pulverised into a powder and mixed with a combination of oils or an acidic solution such as lemon juice. The resulting paste, known as red henna, can then be applied to the skin or hair to alter its colour. The change in colour is due to dye molecules in the henna tree's leaves called lawsone. When lawsone comes into contact with skin cells, it latches onto a protein called keratin, which holds onto the dye until the skin cells are naturally exfoliated away. Once the henna paste is applied, it typically needs to sit on the skin for several hours for the lawsone to penetrate deep enough through the skin's cellular layers to stain for a few weeks.

Did you know?

Henna leaves contain 0.5 to 1.5 per cent lawsone

Another additive called *p*-Phenylenediamine (PPD), an ingredient in hair dye, has been added in recent years to create 'black henna' in some parts of the world. However, the use of PPD has been made illegal in many places, including the UK and EU, because it poses a risk of causing severe skin reactions.

DEEP WITHIN THE SKIN

How far into the skin can henna penetrate?

1 HENNA PASTE

Henna is applied directly to the skin so the lawsone molecules can penetrate skin cells and bind to keratin molecules.

2 STRATUM CORNEUM

This is the outermost layer of the skin's epidermis, where keratin-carrying skin cells called keratinocytes rapidly reproduce.

3 DEEP SATURATION

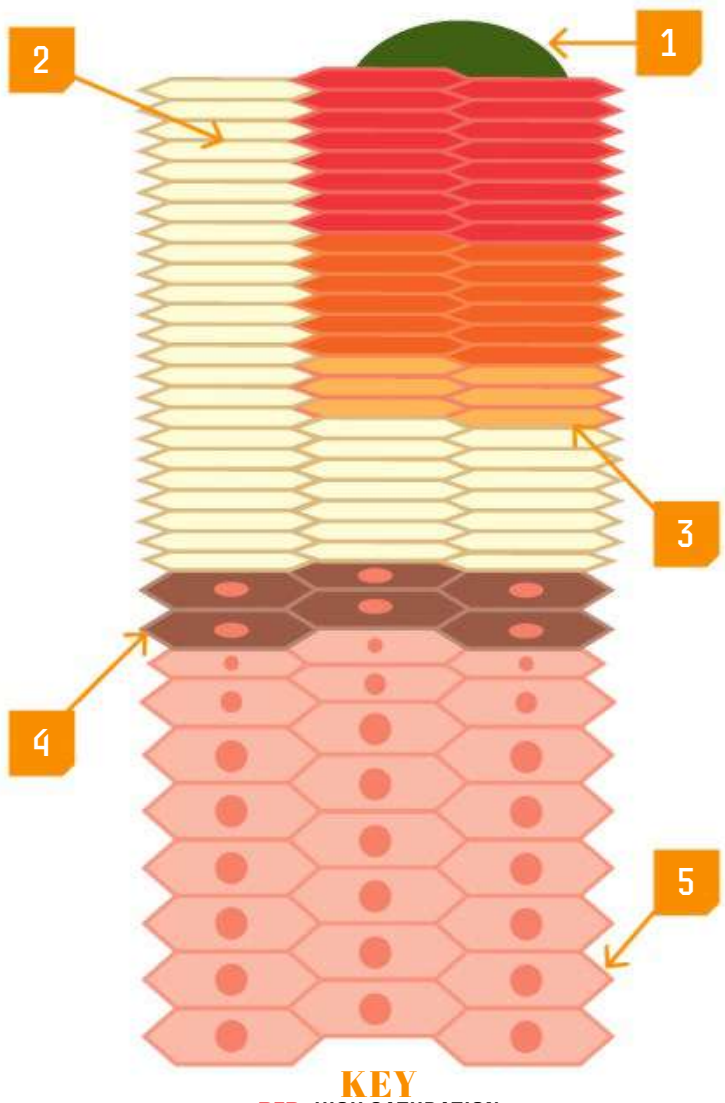
When applied to the thickest layers of skin, found on the back or on the hands, lawsone can penetrate up to 30 cell layers deep.

4 GRANULAR LAYER

Henna doesn't penetrate into the granular layer, which acts as the skin's impermeable barrier against water.

5 BASAL LAYER

The innermost layers of the skin, where new protective keratinocytes are produced.



KEY
RED: HIGH SATURATION
ORANGE: MEDIUM SATURATION
YELLOW: LOW SATURATION

ANCIENT ORIGINS

The exact origins of henna are difficult to determine. There's evidence of the dye being used in early Babylonian civilisations from around 1894 to 539 BCE and during the time of ancient Egypt, between 3100 and 395 BCE. Henna was used to decorate the bodies of the deceased, and in some cases on the strips of linen wrappings used for mummification. Much like the keratin found in hair and nails, lawsone is resistant to decay and remains on the body after death. When archaeologists examined the remains of the Egyptian pharaoh Ramesses II, also known as Ramesses the Great, they discovered that his hair, while white at the point of his death, had been stained bright orange with henna.

He wasn't a redhead when he died, but the remains of Ramesses the Great are orange thanks to henna hair dye

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TITANS OF SPACE

These pioneering space entrepreneurs are helping space exploration take off

WORDS
AILSA
HARVEY

DID YOU KNOW? Rocket Lab has deployed 170 satellites as of September 2023

SMALLSATS, BIG IMPACT Peter Beck

When he was a child growing up in Invercargill, New Zealand, Beck already knew he wanted to build rockets. Despite most people gaining access to space through a university degree, Beck chose not to go to university when he saw no courses that would teach him what he wanted to know: how to build a rocket engine. He had envisioned his future career but aged 18 in 1995, New Zealand had no space industry. Instead, Beck worked in a local tool factory so that he had access to its machines.

His passion for space gained Beck his first investor, internet entrepreneur Mark Rocket, in 2007. Together they launched Rocket Lab, a small satellite-launching company that now has the highest launch success rate of any rocket company. Achieving his dream, Beck's company builds reusable and lightweight rockets that provide small satellite owners with access to orbit. These satellites can be used to fight climate change, aid emergency services and assist student and scientist research.

Beck holding one of Rocket Lab's 3D-printed engines

INSIDE BEAM

How the Bigelow Aerospace habitat will be used

1 SIZABLE SPACE
BEAM is 16 cubic metres, but is launched at one-tenth this size.

2 ACCOMMODATION
The module can house up to six people at a time. They move around by holding onto these bars.

3 BULLETPROOF WINDOWS
There are four windows to provide external views. These protect against space debris contact.

4 LABORATORY
Plants can be grown for food or experimentation.

5 ENGINE
The modules have engines at the rear that can be fired to keep the vessel in orbit.

6 CLOTH WALLS
This soft, black wall can be put up in different sections of the module for privacy. The white box to its right is the toilet.

7 SOLAR PANELS
The habitat's electricity is generated by these solar panels.

8 AIR CIRCULATION
The air supply from the ISS is circulated through the module.

Did you know?
Bigelow believes that aliens have visited Earth

GROWING THE ISS Robert Bigelow

Bigelow combined his fascination with space travel and expertise from his University of Nevada real-estate degree to start the company Bigelow Aerospace in 1999. The Las Vegas-based company has produced expandable habitat pods, used by NASA and private companies, which greatly reduce the cost required to launch such structures. The Bigelow Expandable Activity Module (BEAM) attaches to the Tranquility module of the International Space Station (ISS). During transport on a rocket, BEAM takes up limited space, but when it's deployed there's ample room for astronauts to live and conduct research inside the module.

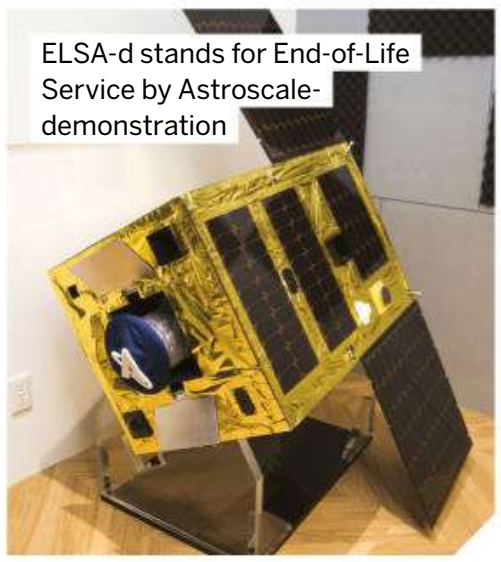
Bigelow standing in front of the BEAM habitat

© Getty / Illustrations by Adrian Mann

SPACE SWEEPER
Nobu Okada

When Okada was 15 years old, he attended the United States Space Camp, leaving his home in Japan. There, he met astronaut Mamoru Mori, who gave Okada a message that said 'the challenge of space is waiting for you'. This camp is what drove Okada's desire to explore space, but he didn't act on this message until later in his career. First he worked in consulting and finance, which he was successful in until he was almost 40 years old. Okada then decided it was time for a career change and that he wanted to work on space technology. After looking into the conditions in space and the accumulation of space junk, he felt that he should try to remove items from space rather than add more.

In 2013, Okada founded Astroscale, a company specialising in space debris removal. In 2021, the ELSA-d satellite was launched. The satellite incorporated a magnetic system that could attract space debris. Since then, Okada has been working on technology that can collect older space junk that's harder to capture because it wasn't built with retrieval in mind. The new debris collector craft has a robotic arm that could be used to pull objects down to a low orbit one by one. Astroscale aims to release this technology in 2026.



ELSA-d stands for End-of-Life Service by Astroscale-demonstration

SERIAL ENTREPRENEUR
Susmita Mohanty

Mohanty isn't just a space entrepreneur – she's the first one to be the founder of three companies on three continents. These are Earth2Orbit, India's first private space company; a San Francisco-based space consulting company called Moonfront and a space architecture company called Liquifer which she founded in Vienna. Mohanty's experience makes her highly qualified to succeed in the space industry. She worked for NASA on Shuttle missions at Johnson Space Centre in Houston and in business development for the International Space Station program. It was her father who originally inspired her to pursue a career in space research.

Mohanty, who grew up in Ahmedabad in the Indian state of Gujarat, completed an electrical engineering bachelor's degree at Gujarat University before gaining two master's degrees: industrial design at the National Institute of Design in Ahmedabad and space studies at the International Space University in Strasbourg.

A spaceship designer, Mohanty was born in 1971

TRANSFORMING ROCKET PRODUCTION
Tim Ellis

Aerospace engineer Tim Ellis, from Texas, had originally planned to become a screenwriter. However, during his first year at the University of Southern California, Ellis switched his program for aerospace engineering. This led to him carrying out three internships at the company Blue Origin during his time at college. As a graduate, Ellis joined the team at Blue Origin, where he made 3D-printed rocket parts. This sparked his interest in using computer programming to quickly and precisely manufacture high-performance rocket components. Ellis then cofounded Relativity Space with his old classmate Jordan Noone, and they attempted to send the first fully 3D-printed rocket into space. They succeeded with the Terran 1 rocket and are now working on the new Terran R rocket, which can be pieced together in their factory with printed aluminium alloy in just 60 days. To make its engine, the entrepreneurs developed the world's largest robotic metal 3D printer.

Relativity Space's Ellis is from Texas

5 LANDING LEGS
These legs extend for landing and rocket reuse.

4 FIRST STAGE
After separating, the first stage uses cold gas to flip around and reverse its path.

DID YOU KNOW? Astroscale targets space junk at altitudes between 310 and 500 miles

Spelfie uses Airbus satellites to capture images for its application users

TAKING A SELFIE FROM SPACE

Chris Newlands

In today's digital social media era, taking photographs of yourself, also known as a selfie, has become a popular method of capturing memories of a scene or moments with a group. Entrepreneur Chris Newlands has taken these snapshots to new heights with his company Spelfie. Newlands, from Glasgow, is the CEO of the company, which launched in November 2019. The idea is to capture unique images of significant events from space. Using the Spelfie smartphone application, users can take a selfie of the moment they wish to capture, such as a wedding, concert or other organised event. The same scene captured in the selfie is also captured in a real-time satellite image to show the event as seen from space.

Following Spelfie, Newlands launched a sister app called Tripsology. This application uses air-quality data from space and Earth to inform travellers of the air-pollution status in specific locations.

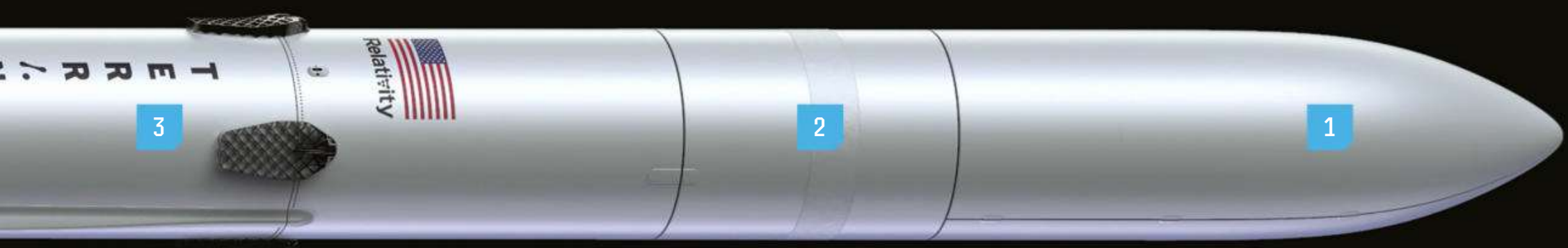
An example of a Spelfie selfie, also captured overhead in space

RELATIVITY'S ROCKET

The 3D-printed Terran R is built so that the first stage can be reused

Did you know?

The Terran R rocket is 82 metres tall



3 INTERSTAGE
Liquid natural gas and liquid oxygen are stored in the interstage.

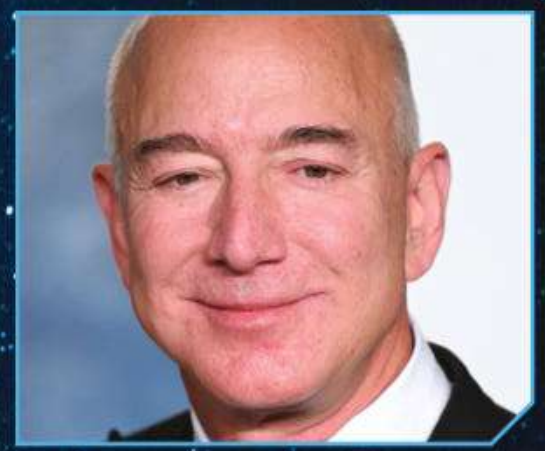
2 SECOND STAGE
Inside the second stage is a 3D-printed engine called the Aeon Vac.

1 PAYLOAD FAIRING
The maximum payload for a reusable fairing to low-Earth orbit is 23,500 kilograms.

© Alamy / Getty / Relativity / Spelfie

THE BILLIONAIRE SPACE RACE

How three of the world's wealthiest space entrepreneurs have battled to win the space tourism race



Did you know?

New Shepard is named after US astronaut Alan Shepard

SPACE X
Elon Musk

Musk grew up in South Africa and later acquired Canadian citizenship, moving to America when he was 18 years old. He is best known as the founder of car manufacturer Tesla, electronic payment company PayPal and private aerospace company SpaceX. Due to his strong belief that humans need to start living on planets other than Earth to survive, Musk launched SpaceX in 2002. The goal was to make rockets that were more affordable than those before it. SpaceX's Crew Dragon spacecraft took its first crewed flight to space in May 2022. Astronauts Doug Hurley and Robert Behnken were launched to the International Space Station, which orbits at an altitude of around 248 miles. The bell-shaped capsule can carry seven people at a time to and from Earth orbit. Unlike similar commercial spaceflight designs, it can carry 6,000 kilograms of cargo back from the ISS after delivering astronauts. Although not the first to fly to space, it was the first private spacecraft to visit the space station.

VIRGIN GALACTIC
Richard Branson

This British entrepreneur founded Virgin in 1972. It was initially a music business, but he soon added other areas to the brand, including phone, cosmetic, train and aerospace businesses. Branson's first rocket-powered spaceplane flight took off successfully in April 2023. But on the fourth test flight by Virgin Galactic, the vehicle broke apart, resulting in co-pilot Michael Alsbury losing his life. This tragedy resulted in unpowered gliding technology being added to the following spaceplane, for safer landings should a similar accident occur. Branson became the first to reach space in his commercial spacecraft, just over a week before Bezos achieved the same feat. However, Branson's spacecraft reached an altitude about 6.2 miles shy of New Shepard. The craft was called VSS Unity, and instead of launching from a rocket, it took off from an aeroplane at 9.3 miles altitude. When the passengers reached the edge of space, they took off their seat belts to experience weightlessness. Then the plane flew back to Earth for landing.

BLUE ORIGIN
Jeff Bezos

Ever since Bezos was in high school, he had hopes of becoming a space engineer. He once told his peers at school about the human impact on the planet. The closing point of his speech was to send humans to space. Today, Bezos is famous for being the founder of Amazon and the commercial space company Blue Origin. Blue Origin was founded in 2000, but for the first decade the company's plans were kept relatively secret. A launchpad was purchased in 2003, and Bezos' engineers began the process of building the New Shepard spacecraft. On 20 July 2021, Bezos, his brother Mark Bezos, pilot Wally Funk and Blue Origin's first customer Oliver Daemen flew into space. They reached an altitude of 62 miles – flying just past the Kármán line – before returning to Earth. The flight took 11 minutes, travelling three times the speed of sound, and the astronauts experienced three minutes of weightlessness before returning to Earth via parachute.

68 MILES

56 MILES

31 MILES

START

GLIDE TO LANDING SHIP

ROCKET LANDS AUTOMATICALLY

TRANSPORT PLANE VMS EVE

ROCKET LANDS AUTOMATICALLY

TOUCHDOWN AFTER TEN MINUTES

DRAGON

VSS UNITY

NEW SHEPARD

DID YOU KNOW? SpaceX's Falcon 9 is the biggest commercial rocket

© Getty / Illustration by Adrian Mann

10 BIGGEST MYTHS ABOUT THE SUN

It may be vital to life on Earth, but there are a lot of misconceptions about our star

WORDS DR LUCIE GREEN

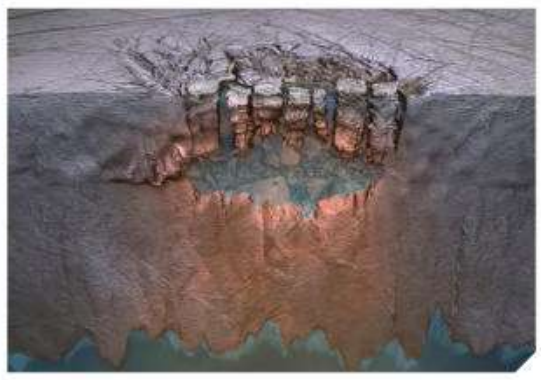
1 THE SUN IS AN AVERAGE STAR

Our Sun is a middle-aged star that doesn't seem remarkable in any way. It's not particularly large or small – red giant stars are hundreds of times larger and red dwarfs are much smaller. The Sun seems to sit nicely in the middle of this range of sizes. Stars are not only classified by their size, though. The light they emit is also used, as this is easily measured. The Sun is a G-type star and has a surface temperature of around 6,000 Kelvin. This is where we start to see that this is not an average star, after all. In fact, 95 per cent of all the other stars that we see in the night sky are cooler than our Sun. Our star is in the top percentage in terms of surface temperature and brightness.

DID YOU KNOW? The Sun contains 99.8 per cent of the total mass of the Solar System

THE SUN MAKES LIFE DIFFICULT

2 Our exploration of the Solar System has shown we need to broaden our horizons when thinking about where life might form. The habitable zone around a star is considered a good place to look, as this is where the temperature should allow liquid water to form on its surface – and water is thought to be necessary for life. Earth is in the Sun's habitable zone, and Mars is just outside it. However, liquid water has been found in some unexpected places outside of this zone.



Life might have found a way on scorching Venus or on Saturn's moon Titan

THE SPACE BETWEEN THE SUN AND EARTH IS A VACUUM

3 Before we sent spacecraft into space, it was thought the area between the Sun and Earth was empty – a perfect vacuum. So it came as a complete surprise when the first spacecraft to venture beyond Earth discovered a stream of particles constantly flowing out from the Sun. We call this the solar wind, and it blows out to vast distances. In 2013, Voyager 1 became the first human-made object to travel outside the bubble created by the solar wind.

Voyager 1 launched in 1977, but only left our Solar System in 2013

IF YOU REPLACED THE SUN WITH A BLACK HOLE, THE PLANETS WOULD BE SUCKED IN

4 The Sun is the most massive object in the Solar System, and all of the other objects in the system orbit around it as a result of its immense gravitational field. It's sometimes speculated that if the Sun were replaced by another object – such as a black hole, for example – then the planets would either be sucked in or ejected outwards. This would only happen if the mass of this new object, and therefore the gravitational pull it exerted, were different to that of the Sun. It's the amount of mass, not the type of object, that matters.

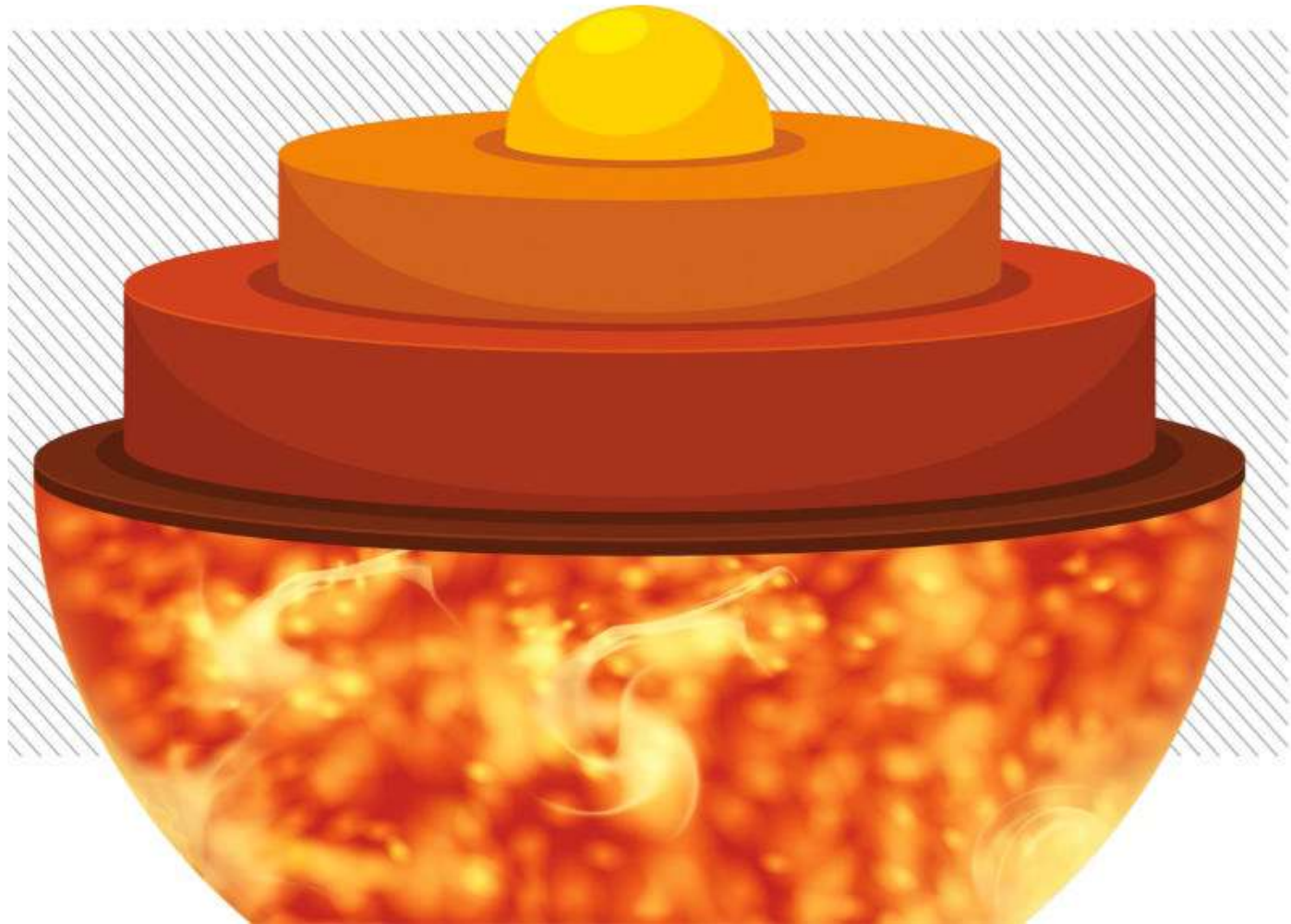
Did you know?

The hottest part of the Sun is its core, reaching 15 million Kelvin

IT HAS A SOLID SURFACE

5 The Sun can be looked at safely through a filter so that most of its dazzlingly bright light is blocked. When viewed this way, you can see that it has a clear edge. Even if you zoom in by using a large space telescope, this edge is still well defined. This gives the impression that what you are looking at is a solid surface, but this is far from the case.

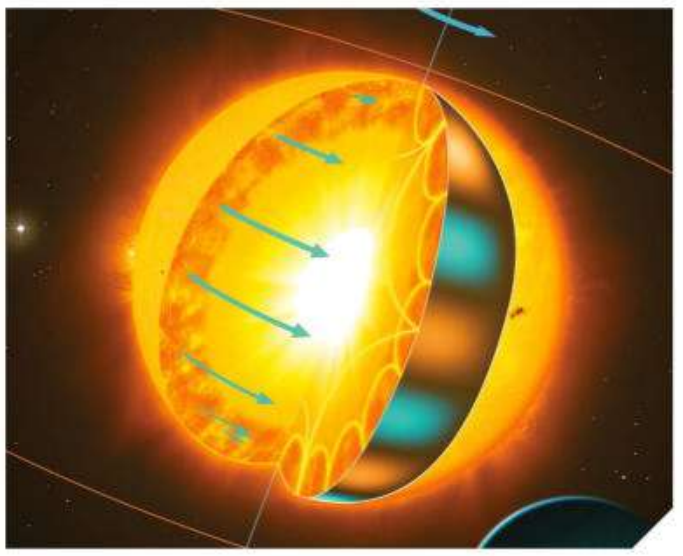
Instead, what you are seeing is the top of a layer of gas that's only around one per cent as dense as the air around us. But it's an important layer, as it is where the gas goes from being opaque to transparent, meaning that the light generated inside the Sun can escape. This is the visible surface of the Sun, and because of this it's called the photosphere. The photosphere is only 310 miles thick, so compared to the overall diameter of the Sun, which is around 869,919.7 miles, this thin layer of tenuous gas certainly looks like a sharp edge to us.



© NASA / Getty

SOLAR WIND REACHES EARTH'S ATMOSPHERE TO CAUSE AURORAE

6 The solar wind carries with it some of the Sun's magnetic field, and it blows over all objects in the Solar System. But the solar wind can never reach the atmosphere as we are surrounded by Earth's magnetic field. The solar wind can only produce aurorae by distorting our magnetic field, either by pushing on it or by breaking it open and causing it to reconfigure. When this happens, electric currents start to flow. If these currents flow through the top layers of the atmosphere, aurorae are produced.

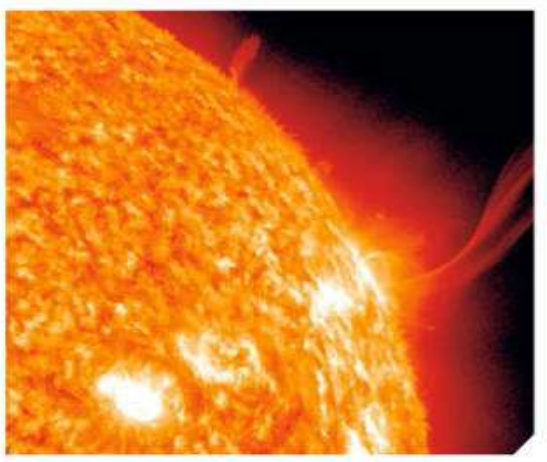


IF THE SUN DIED, WE'D KNOW IN JUST OVER EIGHT MINUTES

7 Sunlight travels at about 186,282 miles per second, meaning that it takes eight minutes and 20 seconds to reach Earth after leaving the Sun's visible surface. But the origin of sunlight is in the thermonuclear fusion that takes place in the centre of the Sun – sunlight only reaches the Sun's surface after hundreds of thousands of years, as it has to get through the star's dense interior layers of gas. If fusion switched off right now, the Sun would keep shining for hundreds of thousands of years.

THE SUN IS A BLANK DISC

8 When we look up at our star, it appears to be a yellow disc with no surface features. But when viewed through special filters, we can see that it's blemished by dark spots, the number of which varies over time. Using an X-ray or ultraviolet telescope on a satellite shows that the Sun has a million-degree atmosphere that's normally hidden from view, but is full of beautiful curved and sinuous structures. These are created by immense magnetic fields, which give us a dynamic and variable star.



The Sun's surface may look unblemished to the naked eye, but it's covered in curved structures

THE SUN'S MAUNDER MINIMUM CAUSED THE THAMES TO FREEZE

9 The Little Ice Age is a time of cooling that occurred roughly between the 14th and 19th centuries. During this time, the River Thames in London froze over, albeit on rare occasions. During a period of around 70 years in the second half of the Little Ice Age, at the end of the 17th century, the spots that normally pepper the visible surface of the Sun vanished. This time is now known as the Maunder minimum, and it has been suggested that this was responsible for the Little Ice Age. Although there is some indication that Northern Europe did have some very cold winters during the time of the Maunder minimum, the relationship between solar activity and Northern European temperatures is complex. What is known, though, is that the Thames froze over because it was quite a different river back then. It was much wider and slower moving. What's more, the old London Bridge sat upon many narrow arches that caught bits of floating ice, creating an ice dam, meaning it was much easier for the river to freeze over.

DID YOU KNOW? The Sun is slowly getting warmer. In a billion years' time, it will be ten per cent brighter than it is now

EARTH'S DISTANCE FROM THE SUN CAUSES THE SEASONS

10 The Sun is the Solar System's source of heat and light, so the closer you are to it, the more light and heat you receive. But what does this mean for us on Earth? Our orbit around the Sun isn't perfectly circular, but it's close. It means that as Earth orbits around the Sun, its distance away from it is anything between 91.3 million and 95 million miles – a variation of four per cent. But this isn't enough to cause a noticeable difference in temperature and drive our seasons. What does make a noticeable difference is how the Earth rotates. Earth rotates about an axis that's tilted by 23.5 degrees, which means that on one side of its orbit the Northern Hemisphere points towards the Sun, and on the other side of the orbit the Southern Hemisphere points towards the Sun. Whichever hemisphere points towards the Sun receives more sunlight and has longer days.

Did you know?

Our star was born 4.6 billion years ago

© NASA / Getty

HOW A CANAL LOCK WORKS

The essential engineering that enables boats to navigate canals and transport goods inland

WORDS AILSA HARVEY

Whether they're used for recreation or for business, boats are often limited to the perimeters of coastlines. However, thousands of inland waterways and hundreds of shipping canals are hidden away from the oceans. These human-made transport systems enable vessels to move between two large bodies of water, or create a network of routes within a city. The world's waterways are direct courses for shipping vessels that navigate between continents, greatly reducing the mileage covered and reducing shipping times by up to ten days per journey. But not all of the benefits that stem from canals impact the boats that use them. Canals can be multipurpose and are a main source of hydroelectric power generation. This involves installing turbines along canals that are turned by the flow of the

water within them. The canals' kinetic energy is then converted into electrical energy and transported via the electricity grid to nearby homes and businesses.

Being artificial systems, canals require constant upkeep to ensure that waterways remain navigable. They are built near reliable water sources, and the water levels in canals are constantly monitored. Alongside canals, dams are often constructed to produce large water supplies close by. These large bodies of water are then fed into the canals if they begin to dry up. The two main types of canals are waterways and aqueducts. Waterways are more traversable canals, used for shipping and recreation, while aqueducts are mainly used to irrigate farmland, generate electricity and transport drinking water.

Did you know?

The Statue of Liberty was built for the Suez canal's entrance

PANAMA AND SUEZ

Two of the most important shipping canals in the world are the Panama Canal, located in Panama, Central America, connecting the Pacific and Atlantic, and the Suez Canal, which connects the Gulf of Suez, Egypt, and the Mediterranean Sea. The Panama Canal is 51 miles in length and creates a 9,320-mile shortcut for shipping boats travelling between the East and West Coasts of the US. Following its completion in 1914, journeys between the Pacific and Atlantic take half the time than prior to its construction.

Meanwhile, the Suez Canal covers 120 miles and is so vital to global trade that it can't close, even amid global disasters. The canal has been in operation since 1869 and runs between more densely populated lands. This makes the Suez a much busier route than the Panama Canal. The entire length of the Suez Canal remains at sea level, so there was no need for any locks to be built along it.

Over 22,000 ships used the Suez Canal in 2022

CANAL BOAT EVOLUTION

17TH CENTURY

Dutch barge boats were originally used to carry cargo along the Netherlands' rivers. Today, Dutch barges are large, between 20 and 40 metres long, and make for spacious boat homes.

18TH CENTURY

Traditional narrowboats were invented as working boats. These range from 6 to 20 metres in length.

1801

Similar in design to the traditional narrowboat, tug narrowboats were invented to tow other vessels on canals. They have a larger front deck for this purpose.

19TH CENTURY

During this century, canal systems were widened in the UK, France, Germany and the Netherlands, and widebeam boats were invented. These canal boats can be four metres wide.

1950s

An increased number of old working narrowboats were converted into cruiser boats for pleasure. A cruiser boat has a large exposed deck.

©Getty / Alamy / Shutterstock

THE PANAMA CANAL: CROSSING MOUNTAINS

Discover the incredible locks and lakes that allow huge vessels to voyage across this mountainous terrain

Did you know?

There are 150 canals in Venice

3 GATUN LAKE

This 89-square-mile body of water is an artificial lake made by damming the Chagres River. Its water is used to fill the locks during dry periods.

2 GATUN LOCKS

These locks take up 1.8 miles of the canal and consist of three large chambers, each big enough to house the Titanic.

1 ATLANTIC OCEAN

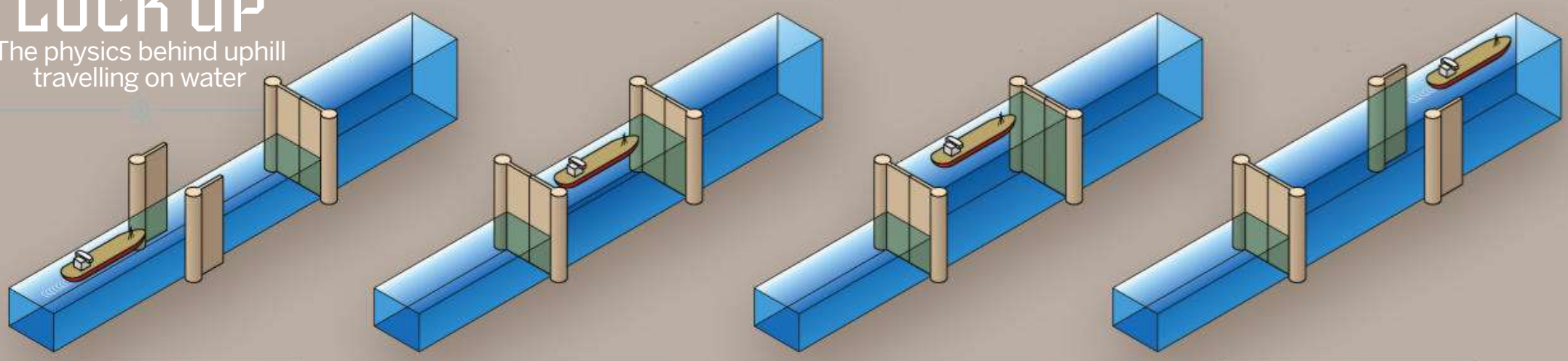
At one entrance to the Panama Canal is Cristóbal Port, which has 3,700 metres of berthing space.

4 LAKE ALAJUELA

At 76 metres above sea level, this lake serves as a backup reservoir for the canal.

LOCK UP

The physics behind uphill travelling on water



1 ENTERING THE CHAMBER

At least one gate needs to be closed. The boat enters from the lower section of the canal through the lock's open gate.

2 RELEASE AND RISE

The lock's gate shuts behind the boat, securing the vessel in the chamber. Valves in the second gate open, causing water to gush into the bottom of the boat's chamber.

3 LEVELLING OUT

As water enters the chamber, the increased volume causes the boat to rise. Eventually, the water pressure will be the same on either side of the second gate and the water level will even out.

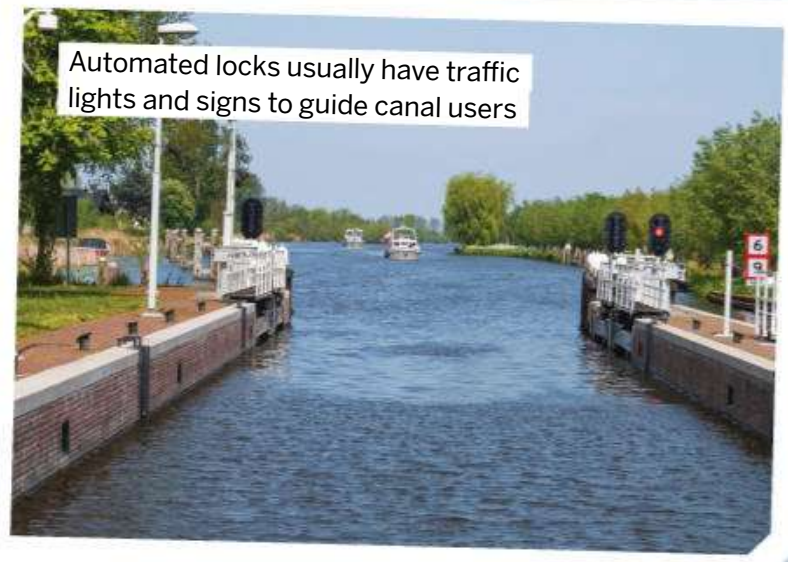
4 RESUMING THE VOYAGE

Now that the water levels are even, the second gate can open and the boat is released from the chamber, now at a higher level than when it entered the lock.

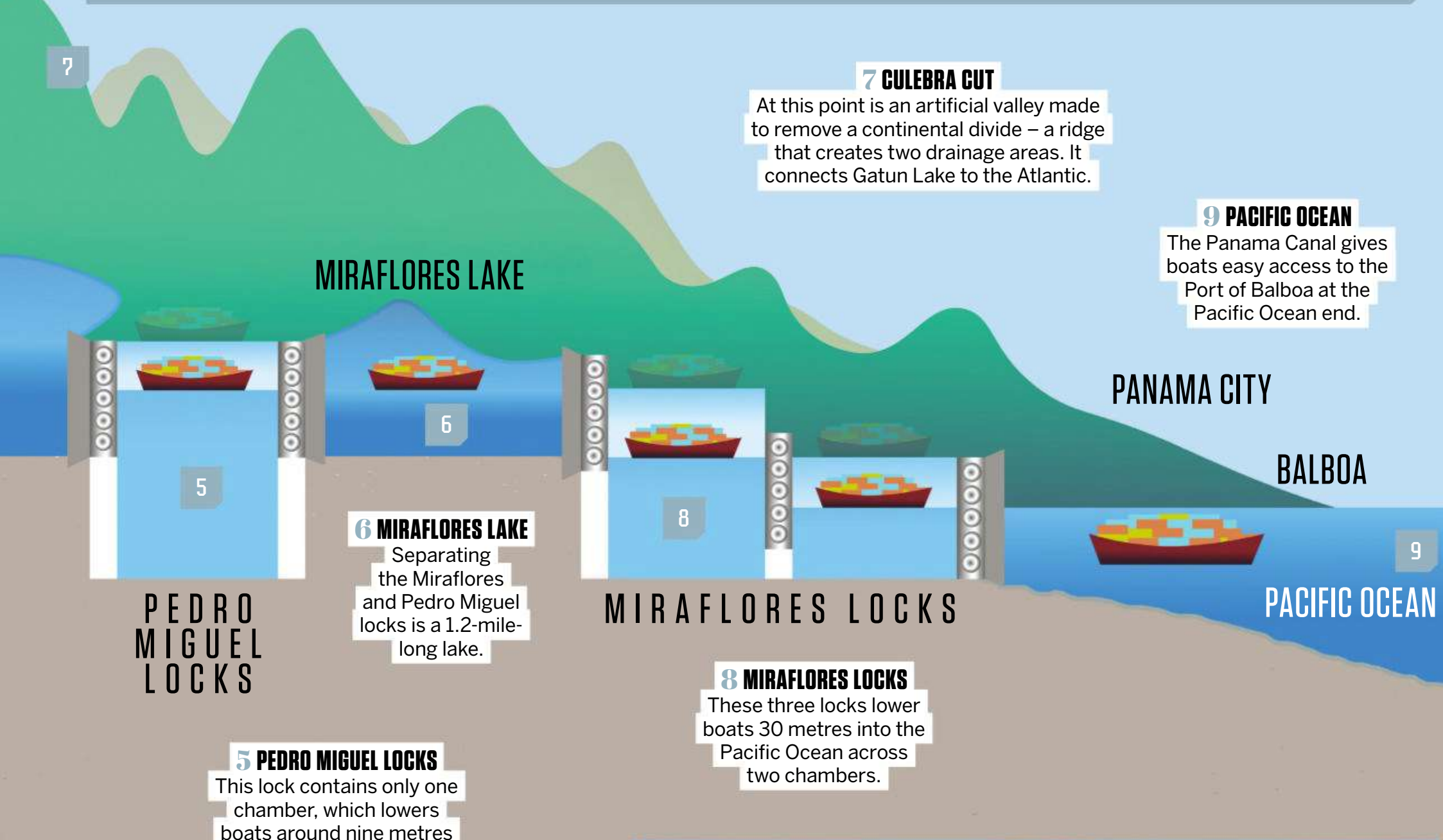
DID YOU KNOW? The longest lock flight in the UK ascends 67 metres and comprises 30 locks

SMARTER NAVIGATION

Canals have served as navigational shortcuts for centuries, but the way they are used is evolving in line with modern technology. Both the boats that pass through and the canals themselves are becoming smarter, making the lives of canal dwellers, operators and shipping employees easier. In the past, all canal locks were guarded and manoeuvred by a lock operator, but today this process can be completely automated. Sensors can detect the presence of a boat at the gate and when inside the chamber and automatically move gates and valves based on the direction of travel. Canal boat owners are likely to have mastered the act of mooring their sizable boats quickly and carefully. However, it can be an elaborate and precise process. Now there is automated docking technology that uses motion and infrared sensors to detect how far away the towpath is and steer boats perfectly into tight spaces.



Automated locks usually have traffic lights and signs to guide canal users



7 CULEBRA CUT
At this point is an artificial valley made to remove a continental divide – a ridge that creates two drainage areas. It connects Gatun Lake to the Atlantic.

9 PACIFIC OCEAN
The Panama Canal gives boats easy access to the Port of Balboa at the Pacific Ocean end.

6 MIRAFLORES LAKE
Separating the Miraflores and Pedro Miguel locks is a 1.2-mile-long lake.

8 MIRAFLORES LOCKS
These three locks lower boats 30 metres into the Pacific Ocean across two chambers.

5 PEDRO MIGUEL LOCKS
This lock contains only one chamber, which lowers boats around nine metres to Miraflores Lake.

The Falkirk Wheel in Scotland replaces a traditional lock. When a boat drives on, the wheel spins to lift it to the upper canal

© Getty / Alamy / Shutterstock

SOLAR-POWERED CARS

This fleet of next-generation vehicles is designed to harness the Sun's energy for fuel

The Lightyear is a promising start to the rise of the solar-powered car

SUNSHINE DRIVING

Take a tour inside the solar-powered Lightyear 0

1 SOLAR PANELS
Around five square metres of curved solar panels cover the car's roof, bonnet and boot.

7 AERODYNAMIC DESIGN
The car has a low drag coefficient – less than 0.19 – to reduce the amount of energy it uses and increase its range.

6 PLUG CHARGE
In addition to the car's solar charging, the Lightyear 0 utilises plug charging to provide around 388 miles of range on a single charge.

2 CARBON BODY
Each body panel of the car is made from reclaimed carbon fibre.

WORDS **SCOTT DUTFIELD**

In 2022, the Netherlands-based automotive company Lightyear premiered the first commercial solar-powered car, the Lightyear 0. Similar to the solar panels that are installed on rooftops, the Lightyear 0 uses Vehicle-Integrated Photovoltaics (VIPV) to transform the energy of sunlight into electrical power. The power is then fed into a 60-kilowatt-hour battery and transformed to turn the wheels' electrical motors and power the car's internal systems. This also means that while the car is out in the Sun, it continually recharges its battery. But the car isn't completely powered by the Sun yet – traditional electric charging is required when the car has used more power than the VIPV can produce. One hour of solar charging produces enough power for a maximum range of around six miles.

Lightyear is one among many different companies that are developing the first generation of solar-powered cars. Up until now, solar technology has been largelgy overlooked by the automotive industry, despite a rise in all-electric vehicles. The biggest drawback of solar-powered transport is its energy efficiency. Along with vehicle propulsion, solar-powered cars need to fuel onboard technology and continuously recharge to meet demand. Current VIPV technologies aren't yet able to generate enough energy to completely power commercial cars. For now, solar-powered vehicles will have to rely on traditional electrical charging to meet their energy needs.

Did you know?
The Lightyear 0's top speed is 100 miles per hour

The Lightyear 0 came with a hefty £215,000 ($268,000) price tag. After only a few months of production, Lightyear filed for bankruptcy. However, after reinvestment in the company, it's back in business and focusing on its more accessible £40,000 ($50,0000) second-generation model. The Lightyear 2, much like its predecessor, is a solar-electric vehicle that can drive for 500 miles before you need to plug it in to charge, which is three times fewer charges than conventional all-electric vehicles. Production of the Lightyear 2 is set to start in 2025.

DID YOU KNOW? The first demonstration of a solar-powered car, William G. Cobb's 'Sunmobile', was in 1955

THE APTERA

Lightyear isn't alone in the solar-power race – the Aptera solar-powered car is hot on its heels. The three-wheeled vehicle uses diamond-shaped solar panels to energise its onboard battery at around 700 watts of continuous charging while out in the Sun. As well as traditional plug charging, the Aptera's solar panels can generate enough energy for 40 miles of additional daily driving alongside its typical 1,000-mile range. Aptera is also one of the most aerodynamic solar vehicles, with a drag coefficient of just 0.13. Typically, a non-racing car has a drag coefficient between 0.3 and 0.4. The less drag the car experiences, the less fuel or electricity it needs to reach a particular speed.

The Aptera can go from 0 to 60 miles per hour in just four seconds

ADAPTING TO SOLAR ENERGY

While vehicles with built-in solar power are largely still in development, companies such as Sono Motors have found a solar solution to assist fossil fuel engines. The Solar Bus Kit is a helpful system that takes the strain off bus batteries to run heating, ventilation and air-conditioning systems, in the process reducing their fuel consumption. The system comprises eight square metres of semi-flexible solar modules, which are retrofitted to a diesel bus. The modules are then connected to a bus' 24-volt battery and become the battery's main supply of electricity, taking the pressure off the vehicle's diesel engine. Sono Motors claims that up to 1,500 litres of diesel can be saved per bus each year, preventing around four tonnes of carbon dioxide from being released into the atmosphere annually.

The Solar Bus Kit allows city buses to harvest solar energy

3 INTERIOR
A combination of plant-based leather and recycled plastic bottles were used for interior materials.

4 ADDITIONAL POWER
The power produced by the VIPV array, or 'Lightyear Layer', supplies around 44 miles of additional range per day.

5 WHEEL MOTORS
Each of the car's four wheels are equipped with independent in-wheel motors to deliver an acceleration of 0 to 62 miles in ten seconds.

© Aptera / Sono Motors / Lightyear

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A NASA APOLLO 15 WATCH

WORTH

£300

This month, every **How It Works** reader has a chance to win a NASA Apollo 15 American Moonphase watch by Xeric Watches. The lunar design celebrates NASA's triumphant mission to the Moon in 1971. Along with a pair of lunar hands and a luminous glow-in-the dark coating, this watch tracks the Moon's journey through its 29.5-day cycle

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Which of these is not a gland in the human body?

A: PITUITARY B: THYROID C: HUMERUS

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BRAINDUMP

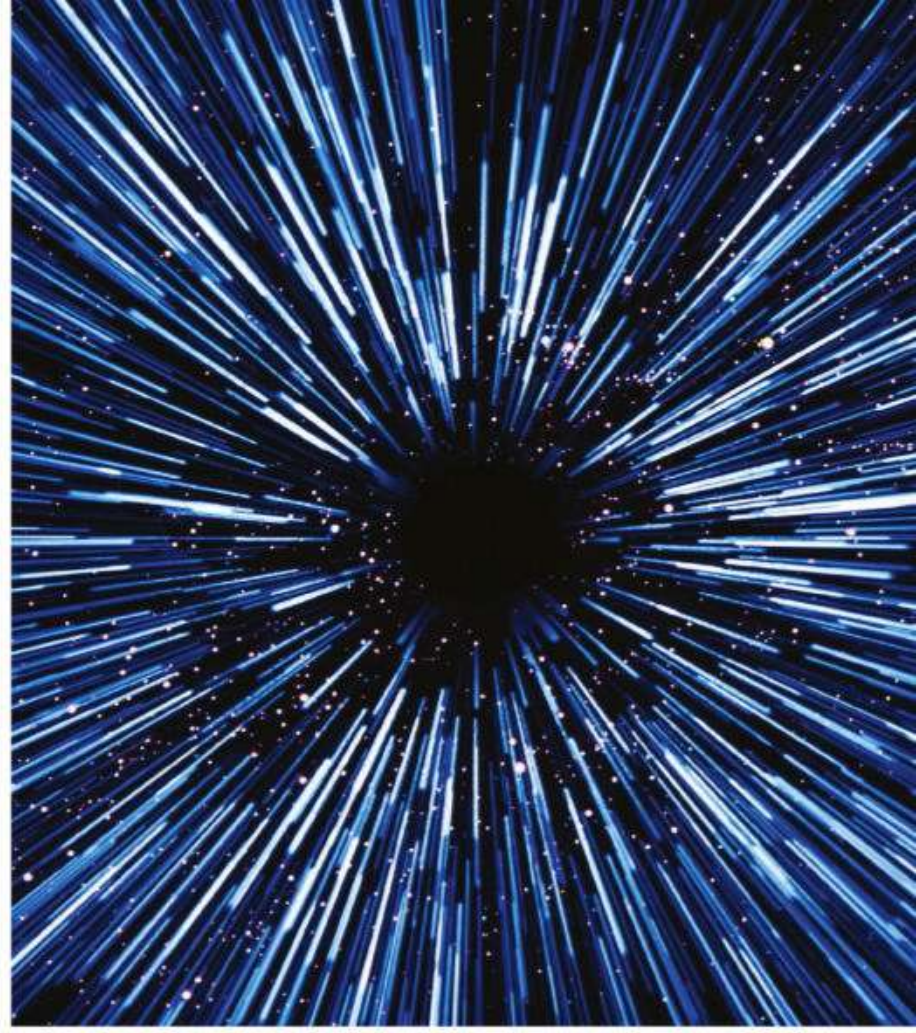
Amazing answers to your curious questions

Could we terraform Mars?

Many scientists believe that it's possible to make Mars habitable, but there's a lot of work to do. First, we need a new atmosphere. On Mars it's about 95 per cent carbon dioxide, and very thin in comparison to Earth's. We also need liquid water, since Mars is currently a desert planet. Since it's further from the Sun, on average Mars has a temperature measuring about -60 degrees Celsius, so we'd definitely need more heat. Finally, Mars would need a magnetic field to hold in that atmosphere, heat and water, as well as protect us from solar radiation. We could help along some of these issues by creating a greenhouse effect on Mars – it's how Earth is warmed, as sunlight is reflected off the planet's surface and is absorbed by gases in the atmosphere. This would require importing or creating those gases on Mars, and there are lots of proposals for how to make that happen... some of which are either not possible with our current technology or are too cost-prohibitive. The answer to whether we could actually live on Mars one day is, for now, a decided 'maybe'.

WHO WERE THE FIRST KINGS AND QUEENS OF ENGLAND?

Some historians think that the beautiful but wicked Ælfthryth was the first queen of England, while others believe Matilda, the daughter of King Henry I, was the first female monarch. Queen Mary I, also known as Bloody Mary after burning many religious opponents at the stake, was officially anointed and crowned, so is generally recognised as the first woman to rule. Early kings of England include Æthelstan, whose victories over the Vikings and the Scots meant he was crowned first king of a united England. However, to complicate matters, his grandfather, Alfred the Great, was the first to be crowned king of the English.



IS THERE A MAXIMUM SPEED AT WHICH AN OBJECT CAN TRAVEL THROUGH SPACE?

The theory of special relativity, proposed by Einstein in 1905, includes the universal constant that nothing can travel faster than light in the vacuum of space. It took several decades to pin down the exact speed of light, but in 1983 it was tied to the definition of the metre by the International System of Units at 299,792,458 metres per second. Theoretically, that's the fastest speed that anything can travel in space. In 2012, workers at the European Organization for Nuclear Research (CERN) announced they had recorded a type of subatomic particle called a neutrino going faster than the speed of light, but this was later shown to be inaccurate – the neutrinos were travelling at the speed of light after all.

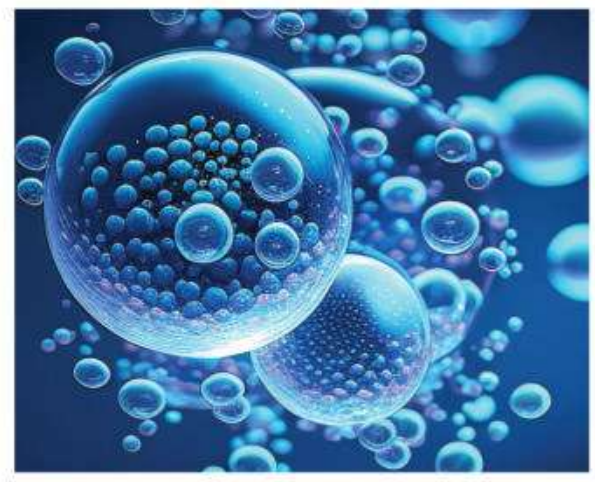
HOW DO ELECTRIC FREEZERS GET SO COLD?

The freezer in your kitchen is at about -22 degrees Celsius. It achieves this using a gas, such as 1,1,1,2-tetrafluoroethane, that has a boiling point not too far below zero degrees Celsius. The freezer compresses the coolant, which heats it, and then passes the hot vapour around the coils at the back. Heat radiates from the coils to the kitchen, and the coolant's temperature drops. As the coolant is under pressure, it condenses, even though it's above its normal boiling point. Then it is pumped to the interior of the freezer, and a pressure valve lets about half the coolant boil off. This drops the temperature of the rest of the coolant, allowing heat to flow from the freezer compartment to the coolant. Once boiled off, it returns to the compressor in order to restart the cycle.

Vapour compression cycling using different gases can achieve much lower temperatures, as low as liquid helium, around -269 degrees Celsius.

WHY ARE BUBBLES SPHERICAL?

The skin of a bubble is composed of a thin layer of water molecules sandwiched between two layers of soap molecules. Water on its own has a high surface tension due to intermolecular forces causing molecules to pull on one another, trying to minimise the surface area and be as flat as possible. Soap reduces this surface tension, but the effect of surface tension is still present in a bubble, causing the bubble 'film' to be stretched. A sphere is formed as it is the shape with the least amount of surface area for its volume.



Did you know?

Each of your eyeballs weighs around seven grams

Why do our eyes take a while to adjust between darkness and light?

At the back of the eye, on the retina, there are two types of photoreceptors – cells which detect light. Cones deal with colour and fine detail and act in bright light, while rods deal with vision in low-light situations. In the first few minutes of moving into a dark room, cones are responsible for vision but provide a poor picture. Once the rods become more active, they take over and create a much better picture in poor light. Once you move back into light, the rods are reset, and so dark adaption will take a few moments again. Soldiers are trained to close or cover one eye at night when moving in and out of a bright room, or when using a torch, to protect their night vision. Once back in the dark, they reopen the closed eye with the rods still working, and as a result maintain good vision. Give it a try next time you get up in the middle of the night.

© Alamy / Getty

BRAINDUMP

WHAT IS THE MAXIMUM DISTANCE THE HUMAN EYE CAN SEE WHEN UNOBSTRUCTED?

Dust, water vapour and pollution in the air will rarely let you see more than 12 miles, even on a clear day. Often, the curvature of the Earth gets in the way first – at sea level, for example, the horizon is only 2.9 miles away. On the top of Mount Everest, you could theoretically see for 211 miles, but in practice cloud gets in the way. For a truly unobstructed view, look up. On a perfectly clear night with no Moon in the sky you can see the Andromeda Galaxy with the naked eye, which is 2.25 million light years away.

DOES SNOW MAKE YOU DEHYDRATED?

Not directly, but eating snow in a survival situation isn't the best strategy. As it's so cold, it will decrease your core temperature, forcing your body to increase its metabolic rate to keep you warm. In these cases, you trade high levels of energy for relatively little gain. Melting the ice to water is a far better option. If you can't do that, sucking on ice is still better as it has more water for the same volume compared to snow. The other problem is that, like drinking from a stream, you don't know exactly what pollutants may be in the snow.

How come babies can swim underwater until a certain age?

This is one of the primitive reflexes that all newborn infants have, but are lost as they grow past six months old. Many of these reflexes are to protect the baby and carry a survival advantage, but some have no benefit. In the swimming reflex, placing a baby face down in water will cause them to kick and paddle. The aim is to buy enough time until someone can come and help. It carries risks, however, since the baby may swallow large quantities of water or aspirate it into their lungs. Another example is the palmar grasp, where placing an object – such as a finger or toy – into a baby's palm will cause a strong grip.

DOES EARTH SPIN SLOWER NOW THAN IT USED TO?

Thanks to thousands of years' worth of observations recorded by astronomers, we know that the Earth's rotation has slowed down over the years. The rotation – or the length of a day – can vary by as much as a millionth of a second. It hasn't been a steady decline, but over that period of time the decline has been up to 25 millionths of a second per year. This is all due to the way that the Moon interacts with the tidal bulges on our planet, but there's also a relationship between the weather and Earth's rotation.

What is the Terracotta Army?

The Terracotta Army, unearthed in 1974, is one of the most exciting archaeological finds in recent history. The figures represent the soldiers of Qin Shi Huang, the first emperor of China. They had been placed in his tomb, an earthen pyramid mound, which was excavated beneath Mount Li. Construction had begun when the emperor was a child – it took many years to build. The tomb represents the royal palace, and the figures inside court residents. Beside the warriors, archaeologists found models of officials and entertainers. There are 8,000 soldiers, each depicted with weapons such as spears, bows and arrows. There are also models of horses and chariots. Made out of yellow clay, the Terracotta Warriors were meant to protect the emperor in the afterlife. Artisans first made the limbs and heads, which were then fired in a kiln. Once assembled, the models were painted and coated with a preservative, but only some colours are still visible. Each figure was given individual features, with details added to the hair and clothes; artists even added muscle tone to the arms and legs. The height of the soldier depended on his rank – the military generals are the tallest figures in the group.

Did you know?

Each figure in the Terracotta Army has its own facial features

CAN SCISSORS CUT GLASS?

Glass is a very brittle material and likes to crack and shatter under pressure. It would not be possible to cleanly cut glass using scissors without cracks appearing and a high risk of the glass shattering. Glass is an amorphous solid, which means unlike most solids it has no repeating arrangement of molecules within its structure. The glass used to make drinking vessels and windows is composed of around 75 per cent silica mixed with sodium oxide and calcium oxide – this is known as soda-lime glass. The best way to cut this type of glass is by scoring the line you want to cut with a glass cutter, then applying some pressure to both sides of this line to achieve a clean break.

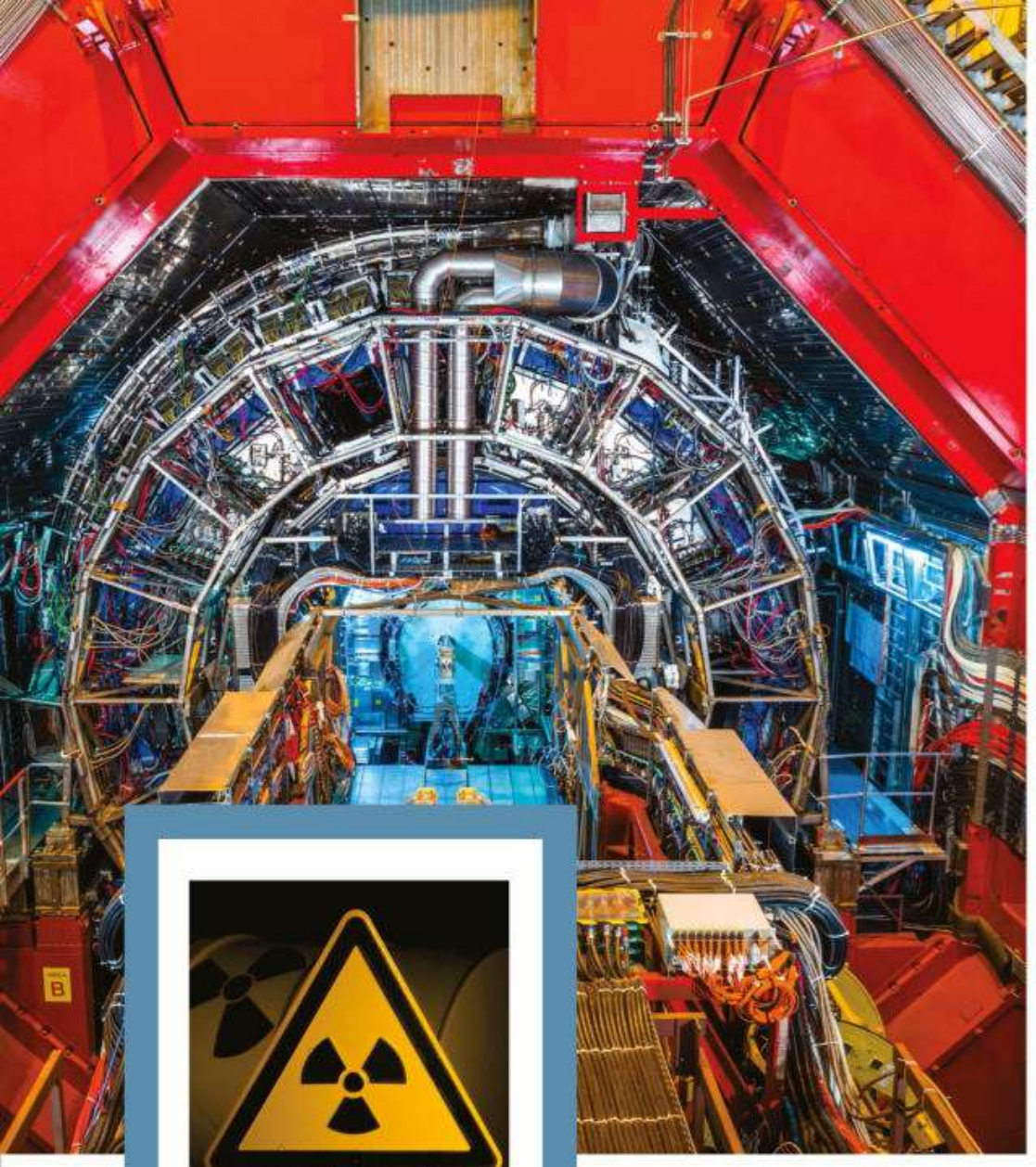
© Getty

How big is the Milky Way?

The Milky Way has a diameter of approximately 100,000 light years, meaning that it would take light that long to travel from one end to the next. Our Solar System – comprising the Sun, its orbiting planets, comets, asteroids and all kinds of other space bodies – doesn't have a clear boundary. But if you use the orbit of its furthest known objects – the cloud of comets called the Oort Cloud, much farther from the Sun than Pluto – it's about two light years. That gives you an idea of how small our Solar System is in comparison to the Milky Way as a whole.

WHEN AND WHERE DID PIZZA ORIGINATE?

The pizza, as a flat bread, can be linked to ancient times. The ancient Egyptians were expert bread-makers, and remains of this type of bread can still be found in many tombs. Flat bread was also popular with the ancient Greeks and the Romans. However, the modern pizza is inextricably linked to Italy, where it first became popular in the 18th century. Naples is thought to be the home of the pizza – a description of this type of dish is given by the French writer Alexandre Dumas in 1830. Its popularity continued to flourish as Italian immigrants brought the recipe to America, along with the rest of the world.



AT WHAT SPEED DOES THE LARGE HADRON COLLIDER SMASH PARTICLES TOGETHER?

The Large Hadron Collider uses an array of 9,300 supercooled electromagnets to guide and accelerate particles – namely protons – around the 17-mile underground ring at CERN in Geneva up to speeds extremely close to that of light. At their fastest these particles travel at around 299.8 million metres per second, completing 11,245 laps of this ring every second. This is equivalent to travelling around the circumference of the Earth seven-and-a-half times in one second.

The Large Hadron Collider has two rings with beams of trillions of particles zooming around in opposite directions. Detectors are placed at certain points where the pipes intersect, causing collisions to occur. As both the particles are travelling in opposite directions at nearly the speed of light, you might expect their combined collision speed to be almost twice the speed of light. However, both particles would measure their collision speed to be less than the speed of light. This seems counter-intuitive, but is accounted for by the slowing down of time and warping of space, as explained by Einstein's special theory of relativity. This explains why no particle with mass should be able to travel faster than light, as it would require an infinite amount of energy to get there.

WHAT IS THE MOST RADIOACTIVE ELEMENT ON EARTH?

Radioactive elements are those made up of atoms with unstable nuclei. Unstable nuclei emit ionising radiation in the form of alpha particles, beta particles or gamma rays in a process called radioactive decay. Polonium is thought to be one of the most radioactive naturally occurring elements due to the high intensity of alpha particles that it emits. Just one gram of polonium can self-heat to temperatures of 500 degrees Celsius. However, there are elements with a higher radioactivity that have been synthesised in a laboratory, such as moscovium, which is so unstable it can only last a few fractions of a second before decaying.

Why do bees buzz?

Bees, like most insects, don't have muscles directly connected to their wings. Instead the flight muscles are attached to the roof wall of the thorax. When it's pulled down, the thorax suddenly pops inward – like the dent that appears when you squash a ping pong ball. This flips the wings upward. A second set of muscles squashes the thorax lengthwise and the roof pops up again. This happens about 190 times a second in honeybees, and the rapid clicking of the thorax wall sounds like a buzz to our ears. Bumblebees also use this feature to shake pollen out of flowers.

WHAT IS CHINA'S FORBIDDEN CITY?

Situated in Beijing, China, the Forbidden City was known as Zijin Cheng – it was named for the North Star, which was thought to be the celestial home of the emperor. Built between 1406 and 1420, its role as an imperial palace continued for 500 years. Covering 180 acres, it was surrounded by a moat and high walls and played home to many magnificent dynasties. The city could house 9,000 people who served the emperor and his many hundreds of wives. Inside the city, ceremony was carefully observed, and all members of the royal family were revered as gods.

© Getty

THE LIBRARY

The latest book releases for curious minds

BOATS! (AND OTHER THINGS THAT FLOAT)

THIS BOOK MIGHT FLOAT YOUR BOAT

AUTHOR **BRYONY DAVIES**
ILLUSTRATOR **MARIA BRZOZOWSKA**
PUBLISHER **WELBACK PUBLISHING**
PRICE **£12.99 / $14.95**
RELEASE **OUT NOW**

Humans have been using boats for thousands of years, in every culture that has had access to a coastline as far back as recorded history goes and for all manner of purposes – like the Vikings, who were famous for using their boats to plunder and conquer, or the Pacific Island nations who literally expanded their horizons and explored new islands. And even though in the last century or so we've found faster or more efficient ways of travelling above and below the water's surface, there are more boats floating on waterways around the world today than there have ever been before. They serve a wide and surprising range of purposes, too, like the freezer trawler, which not only catches fish, but has a processing plant and huge freezers on board to prepare and preserve its catch before it returns to shore during extended fishing expeditions... imagine that the next time you tuck into a fish finger.

Boats! (and other things that float) is an illustrated encyclopedia of craft that humans have invented to carry them over and under the surface of lakes, rivers and oceans. It's packed with familiar ship shapes and nuggets of information, but also a lot of unfamiliar stuff – like the fact that car ferries are known as RORO ferries, as in roll-on, roll-off. Also the Canadian floating home, no mere houseboat or cosy canal boat, is an entire two-storey home that sits on a giant raft in the middle of a lake village entirely occupied by floating homes. Bryony Davies takes us around the world to different cultures across the human history of boating, exploring different categories of boats, including military ships, leisure boats, emergency services and submarines – the latter of which absolutely deserves its own category. You'll be surprised by the range of submersible vessels there have been in the relatively short period of time they've been around. There's no unnecessarily long-winded narrative here; everything is described perfectly well in a series of pithy captions and labels, accompanied by Brzozowska's finely detailed illustrations. If you care for any young minds obsessed with boats, or vehicles in general, you wouldn't go wrong getting them this for their next birthday or as a Christmas gift.

"It's packed with familiar ship shapes and nuggets of information"

SECRET STORIES OF NATURE

A FIELD GUIDE TO UNCOVERING OUR PLANET'S PAST

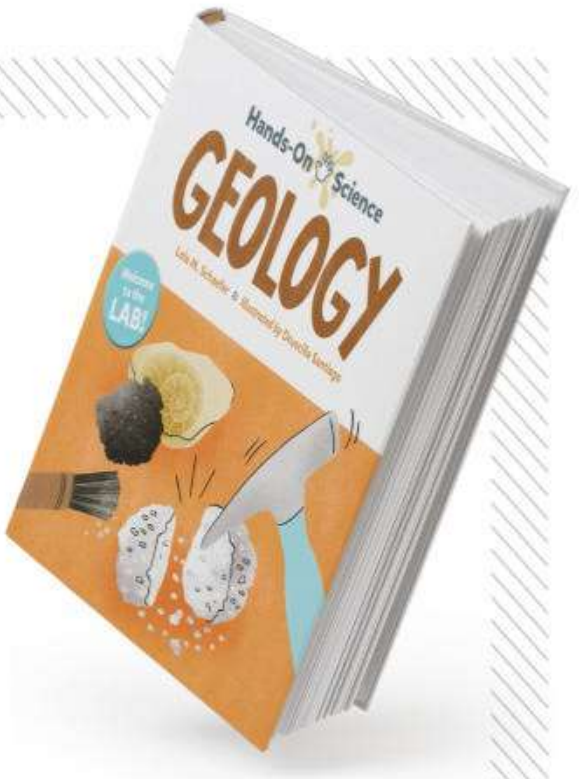
AUTHOR **SASKIA GWINN**
ILLUSTRATOR **VASILISA ROMANENKO**
PUBLISHER **QUARTO PUBLISHING**
PRICE **£14.99 / $24.99**
RELEASE **5 OCTOBER**

This illustrative field guide highlights some of the most fascinating mysteries hidden in the wild. Each chapter delves into different environments and picks out interesting ancient stories of their animal inhabitants, like the dinosaur ants that learned to listen with their feet and the big cats that used them for camouflage. *Secret Stories of Nature* is packed with fascinating tales of the world's wildlife. It's not just the animals in the spotlight, but also some of the natural processes that help scientists uncover their stories, such as ice cores and fossil formation. Along with a heap of new knowledge and intriguing insights, readers are treated to a menagerie of beautiful illustrations that bring each animal to life. For children that are inquisitive about the natural world or excited by animals, this book is a must-read.

HANDS-ON SCIENCE: GEOLOGY

STEP INSIDE THE WORLD'S BIGGEST GEOLOGY LAB

AUTHOR **LOLA M. SCHAEFER**
ILLUSTRATOR **DRUSCILLA SANTIAGO**
PUBLISHER **CHARLESBRIDGE**
PRICE **£15.99 / $16.99**
RELEASE **OUT NOW**

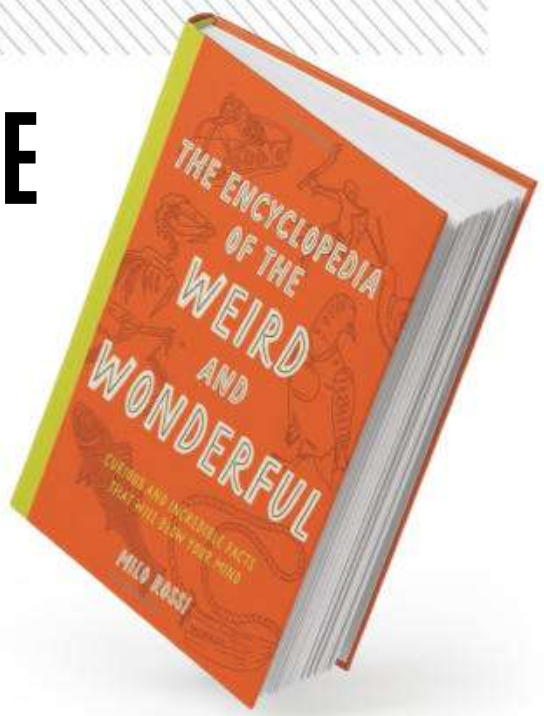


Any child's imagination is sure to be ignited with this brilliantly interactive book about the world's rocks. Tapping, rubbing and slamming on the pages puts children in the place of geologists to examine the rocks around them and understand how they formed. Simply turn the page to find out how blowing on mountains triggers a volcanic eruption or how rubbing your finger along a river can create a canyon. Children will also discover how rocks have impacted human civilisations and allowed us to build rockets to find more rocks in space. After pages of imaginary experiments, children can put their newfound knowledge to the test with a fun practical experiment to test the hardness of real rocks. *Hands-On Science: Geology* opens the door to geology to a young audience through engaging illustrations and innovative interactive content.

THE ENCYCLOPEDIA OF THE WEIRD AND WONDERFUL

CURIOUS AND INCREDIBLE FACTS THAT WILL BLOW YOUR MIND

AUTHOR **MILO ROSSI**
PUBLISHER **QUARTO PUBLISHING**
PRICE **£14.99 / $19.99**
RELEASE **5 OCTOBER**



Archaeologists uncover the human stories of the past piece by piece as clues emerge on the ocean floor, inside caves or buried far beneath the ground. Some of the findings are shocking, some are mesmerising, but almost all of them have a connection to individuals that were born in a different time. In *The Encyclopedia of the Weird and Wonderful*, Milo Rossi has compiled the most incredible findings that drastically separate us and connect us to early humans at the same time.

How did our ancestors navigate brutally transforming climates? How did a biological observation from ancient Egyptians dictate modern marriage proposals? What unusual tools and inventive games were devised to kill one of humanity's worst enemies: boredom? And did you know that humans have been seeking adrenaline thrills throughout history? One example covered in this book is the tradition of nanggol, practised in Vanuatu in the South Pacific. Essentially, it involved bungee jumping from a wooden tower with nothing but a vine attached to your ankle. The vine needed to be the perfect length to survive the fall, and participants needed to settle any ongoing matters before they played with death.

The author tastefully adds humour to the tales of our ancestors in this insightful book. Every fact contains mesmerising details of previous lives, environments and eras. Through each fact and anecdote, elements of humanity connect you to the people of the past, giving the reader a greater understanding of the traditions of modern life that have been shaped by people just like us from different times.

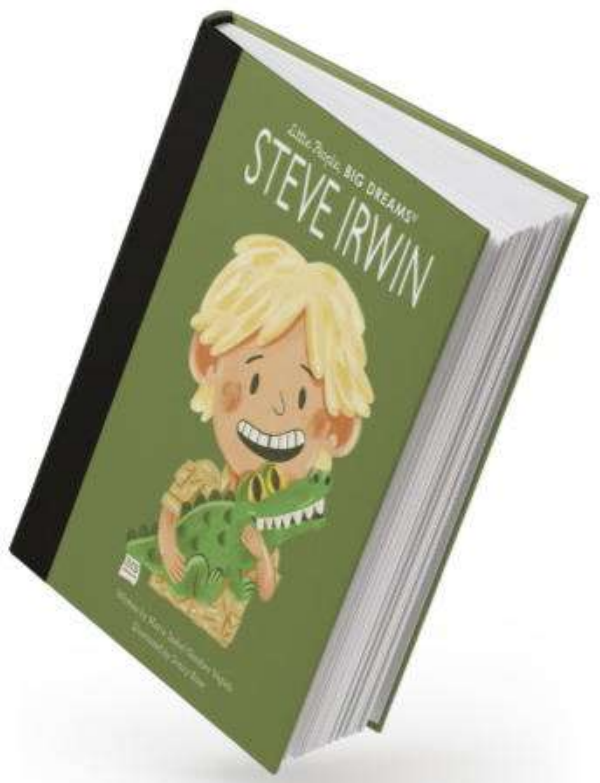
LITTLE PEOPLE, BIG DREAMS: STEVE IRWIN

A PASSION FOR ANIMALS ON PAPER

AUTHOR **MARIA ISABEL SANCHEZ VEGARA**
ILLUSTRATOR **SONNY ROSS**
PUBLISHER **QUARTO PUBLISHING**
PRICE **£9.99 / $15.99**
RELEASE **17 OCTOBER**

Steve Irwin always had a passion for animals, saving his first crocodile at the age of nine. He shared this passion with family and the world, helping conserve wildlife throughout his lifetime and beyond. This biography tastefully captures Irwin's life and his admirable qualities for children aged between four and seven to understand. In the true story of Irwin's life, captured in quirky cartoon illustrations, young children can learn about the importance of family, unique Australian wildlife, environmental safety and how to show compassion for nature.

When Irwin became a famous television host, he used his fame for good, sharing his animal knowledge and his income to start up his own wildlife sanctuary. Only the positive times in Irwin's life are detailed in this story, teaching young children about the legacy Irwin left behind. Each illustration depicts the beauty of the natural world, paints even the scariest animals in an awesome light rather than fear and will keep the reader entertained between every paragraph.



BRAIN GYM

Give your brain a puzzle workout

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

	5		9	8	2		4	3
				5	7	8	6	1
3	7	8	4		1			
	6			1	5		7	
		5				4		
		7		4	3			2
	2		5	3	8		9	4
			1		6		2	
1	3	9	7		4			

MEDIUM

		2		6	1	4		
					4	1	6	5
		1				8		2
3		5	1			2		
4	2		3		5	6		
9		6	4					
5					7			8
		7	2	4		3		
				3			1	4

HARD

8				4	7	1		9
				3		4		
	9		1				6	
	1	5						
	7							
		8			9			2
4								
		6			4	7	1	
9		1		6	8		3	

Word search

Find the following words

SPACE
TITAN
NOBEL
FRUIT
MINES
PHOTO
CANAL
ENERGY
HENNA
VITAMIN
BRAIN
HORMONE

S	C	L	O	F	R	C	A	N	A	L	U	I	T	P
N	P	B	E	L	J	V	I	T	A	N	I	M	R	H
T	I	A	T	H	O	R	M	O	N	E	B	R	A	O
O	N	Z	C	C	A	M	A	L	M	E	F	U	H	T
J	X	E	N	E	R	G	Y	W	I	V	R	S	D	O
B	L	A	O	H	T	O	H	O	R	M	U	N	E	L
H	E	N	N	A	Y	M	I	N	S	E	I	O	Z	U
V	Y	E	M	K	N	E	O	P	A	H	T	R	M	A
J	O	J	O	N	O	B	E	L	W	A	N	C	I	R
T	F	R	U	A	T	V	I	A	L	I	T	O	I	M
A	D	I	O	T	E	N	E	R	A	G	Y	B	R	A
M	N	O	B	I	T	A	N	R	H	O	R	J	O	L
I	S	P	A	T	C	E	B	O	V	R	O	N	T	G
N	R	O	B	P	H	O	F	S	D	K	H	E	N	N
A	L	B	I	O	R	Z	K	L	S	E	N	I	M	Q

What is it?

Hint:
Keeps this animal cool

A

Spot the difference

See if you can find all six changes between the images below

Answers

Find the solutions to last issue's puzzle pages

Q1 ECHIDNA
Q2 GRAVITY
Q3 19TH
Q4 GOOSEBUMPS
Q5 WORLD WIDE WEB
Q6 GEORGE WASHINGTON

What is it?

STAG BEETLE

Spot the difference

QUICKFIRE QUESTIONS

Q1 What's the most common element in your body?

- Gold
- Carbon
- Hydrogen
- Oxygen

Q2 How many bytes of data are in a petabyte?

- 1 trillion
- 1 quadrillion
- 1 million
- 1 billion

Q3 How fast does the International Space Station orbit Earth?

- 17 miles per hour
- 170 miles per hour
- 1,700 miles per hour
- 17,000 miles per hour

Q4 Which animal lays the biggest eggs?

- Duck
- Ostrich
- Elephant
- Golden eagle

Q5 What nationality was Cleopatra, queen of Egypt?

- Greek
- German
- Egyptian
- Roman

Q6 Which of these elements glows green in the dark?

- Nitrogen
- Radium
- Lithium
- Silver

© Getty

HOW TO...

Practical projects to try at home

MAKE A CANAL LOCK

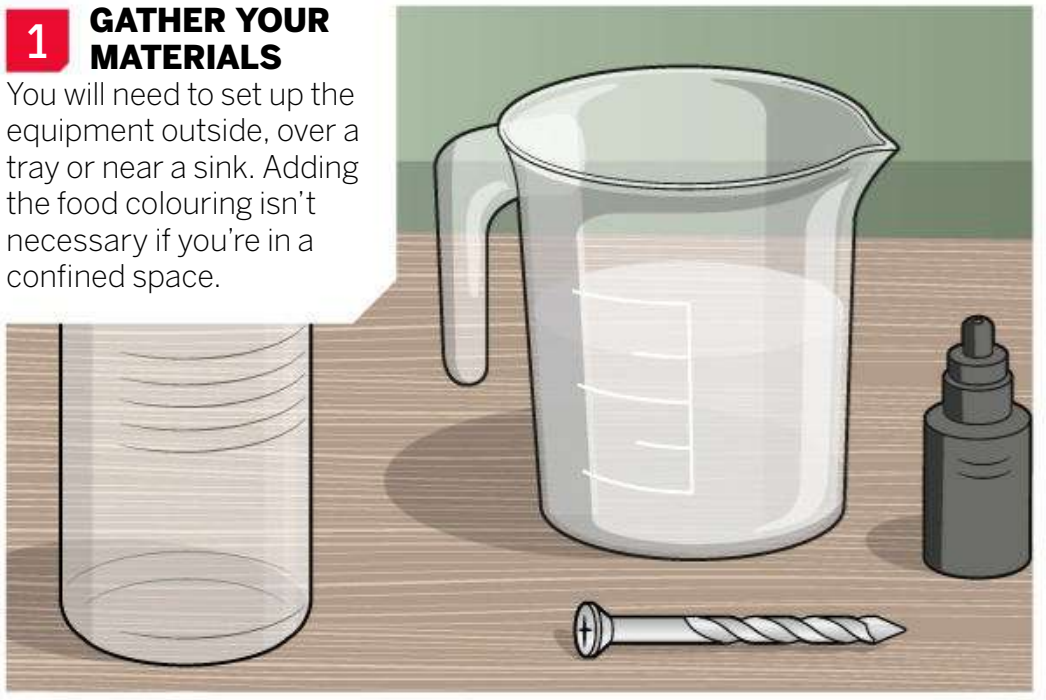
Find out how water pressure helps boats traverse canals quickly

KIT LIST

- A large plastic water bottle
- A nail
- A jug
- A large tray
- Cellotape
- Water
- Food colouring (optional)

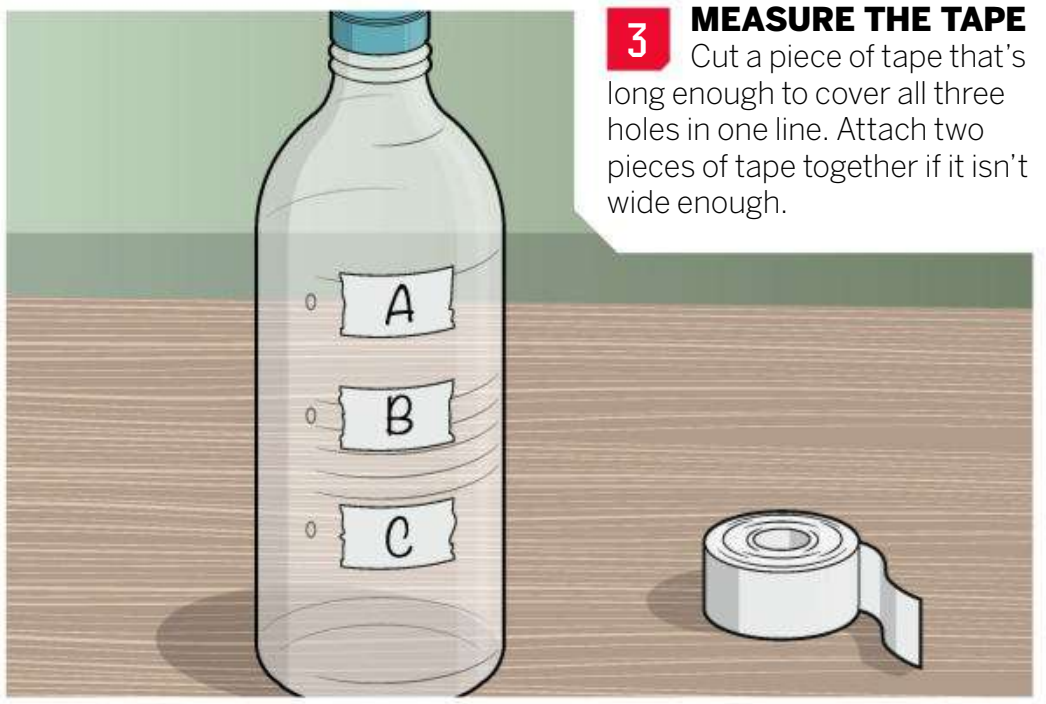
1 GATHER YOUR MATERIALS

You will need to set up the equipment outside, over a tray or near a sink. Adding the food colouring isn't necessary if you're in a confined space.



2 PIERCE THE BOTTLE

At evenly spaced points along the bottle's length, use a nail or other sharp object to make three holes in the plastic. These holes should be in line with each other.

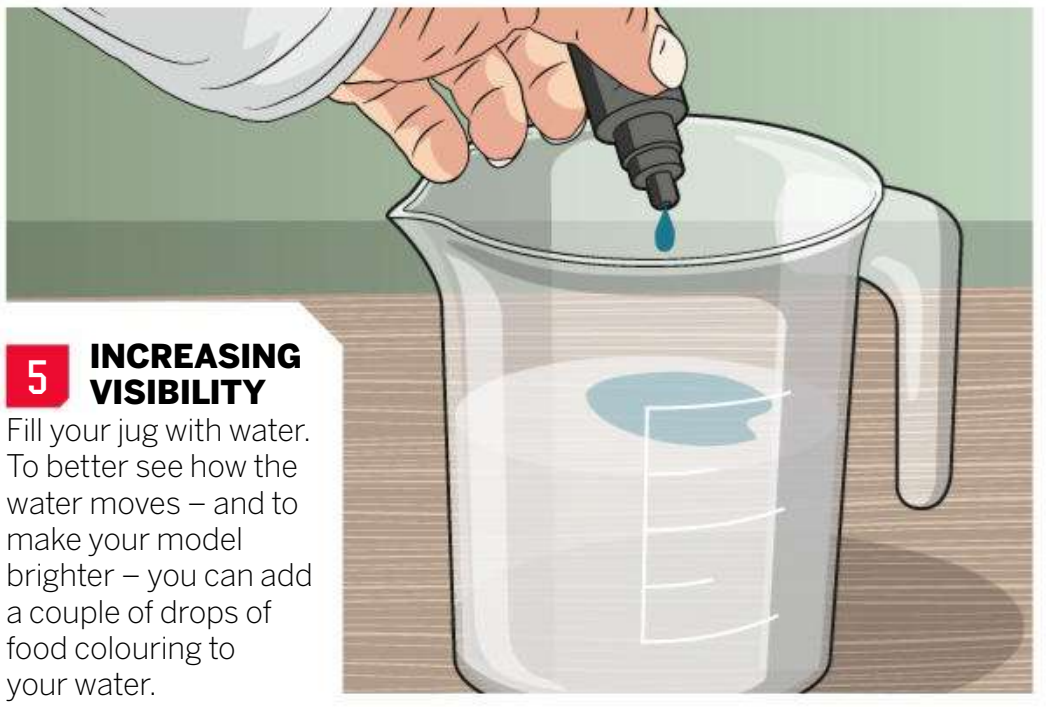


3 MEASURE THE TAPE

Cut a piece of tape that's long enough to cover all three holes in one line. Attach two pieces of tape together if it isn't wide enough.

4 COVER UP

Carefully place the piece of tape tightly over the holes in the bottle. The tape should run along the length of the bottle. Press it down firmly so that no water can escape through later.



5 INCREASING VISIBILITY

Fill your jug with water. To better see how the water moves – and to make your model brighter – you can add a couple of drops of food colouring to your water.

6 FILL THE BOTTLE

Keep your bottle positioned at the edge of the tray or container, with the holes facing into the tray. Add water to the bottle until it's full.

NEXT ISSUE
MAKE YOUR OWN KALEIDOSCOPE

DON'T DO IT ALONE!

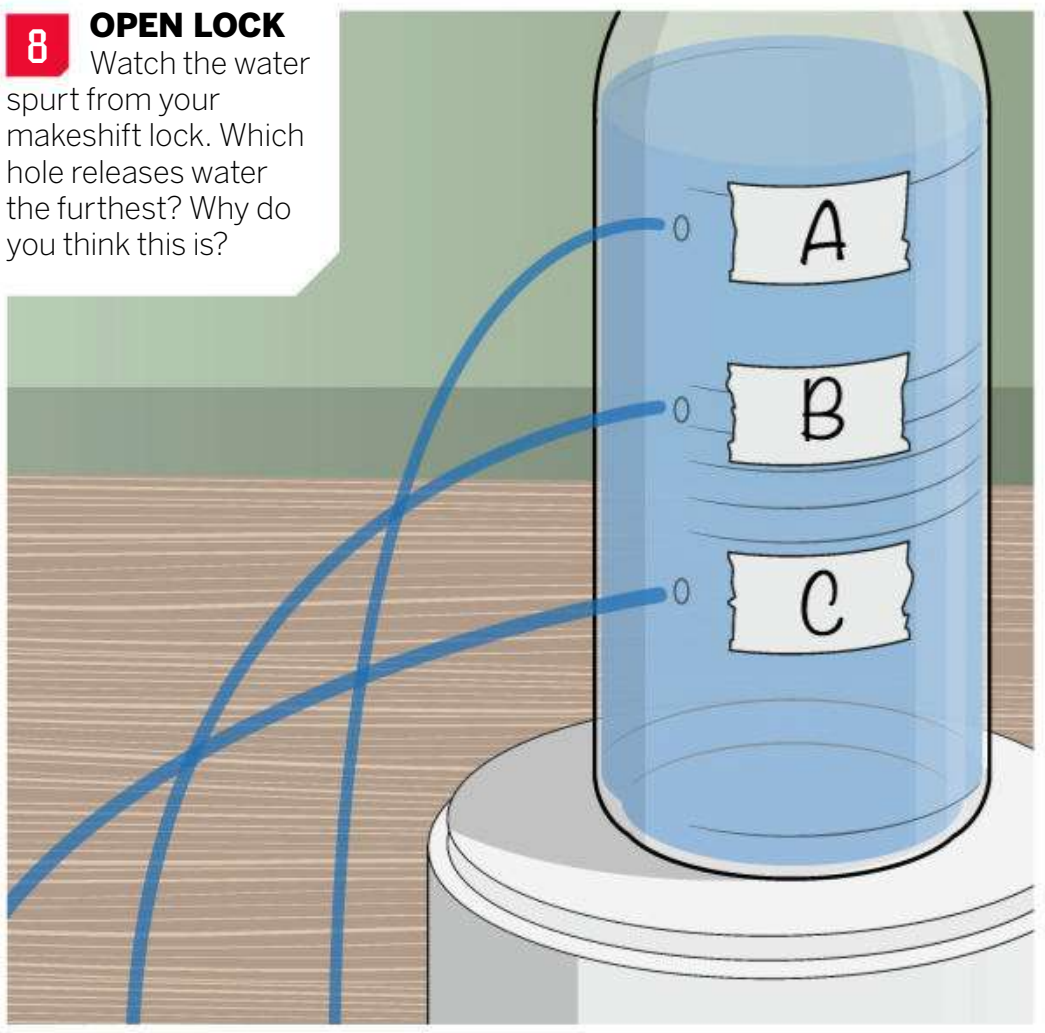
If you're under 16, make sure you have an adult with you

7 PEEL BACK THE TAPE

In one fast action, remove the tape from the bottle. As you do this, make sure the water that escapes is directed into the collection tray.

8 OPEN LOCK

Watch the water spurt from your makeshift lock. Which hole releases water the furthest? Why do you think this is?



SUMMARY

In this experiment, water shoots out further from the bottom of the bottle because there's a much greater volume of water pushing down on it. As depth increases, so does water pressure. This is the same in any body of water, such as in canal locks. The force the water being pushed out of the bottle is equal to the force of the weight pushing down on it. The volume of water held in a canal lock is much greater than that in your bottle. When the holes at the bottom of the gates of canal locks are opened – represented by the peeling of the tape in this experiment – the speed at which water moves from one chamber to the next is much faster. The water keeps gushing into the chamber with shallow water until the water level evens out. Depending on which way the boat is passing through, the levelling water on both sides either lifts or lowers the boat. After this happens, the gates can be opened and boats can pass through. Due to the immense release of pressure and turbulent waters, boaters need to travel with caution through locks.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

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© Illustrations by Ed Crooks

INBOX

Speak your mind

The three stages of hair growth are growth, transition and rest

HAIR-STYLE STEREOTYPES

Dear **HIW**,
How was it decided that long hair is appropriate for women and shorter hair for men? When did men start to have shorter hair as a 'manly' hairstyle?
Fatemeh Bayani

Different countries, cultures and religions have had differing views on hairstyles throughout history. In ancient Greek and Roman cultures, long hair symbolised wealth and power. Both men and women in royal families grew their hair long, as this made them appear elite. Their prisoners and servants were forced to shave their hair to highlight their social status.

World War I saw a trend with men in Western countries cutting their hair much shorter. During the war, soldiers were forced to crop their hair short so that it was easier to wash and avoid lice. As only men were fighting, people began to associate short hair with men. Another reason why many women grew their hair longer in the past is that it was seen as a sign of fertility. Evolutionary psychologists studied the link between hair length and sexual selection. They found that women with longer hair were perceived as being more youthful and fertile.

Biologically, men and women's hair grows at the same rate – about one centimetre a month. However, there is a difference in the three growth stages of hair. Women have more of the hormone oestrogen than men, which keeps their hair in the initial growth stage for longer. Meanwhile, the testosterone produced in the male body makes them reach the third growth stage, or shedding, quicker than females. The result is that women often end up with longer hair.

In many religions, men don't cut their hair, and so the norm is for men to have longer hair. Although there are many factors that can impact societal and biological norms, decisions about hair change regularly throughout history, across different cultures and alongside ever-changing fashion trends.

LETTER of the MONTH

WIN!

AN AMAZING PRIZE FOR LETTER OF THE MONTH

BOATS! (AND OTHER THINGS THAT FLOAT)

Discover some of the more surprising things that float on water, including seaplanes and amphibious cars, as well as finding out how boats float

QUEEN POWER

Dear **HIW**,
If chess was invented a long time ago when it would most likely have been a patriarchy, why is the queen the strongest piece?
Joe Stone-Lee

Although it seems like the inventors of chess provided this female piece with the most power, this wasn't the case in the original game. When chess was invented in 6th-century India, the pieces were very different. The game we are familiar with today is actually a Persian invention derived from the Indian game. In early chess, the queen was a farzin. This was a male figure who served the king. The piece could originally only move one square, unlike the free-roaming queen of today.

When the game became popular in Europe, the name of the piece was changed to a more familiar character in European rule – thus the piece was named the queen. Originally, the queen had little power on the board, but eventually the game was improved to speed up play and allow clever tactics.

Early chess was called chaturanga

CRYING SCIENCE

Dear **HIW**,
Why do people start to cry more when they see other people cry?
Faye Miles

Humans have evolved to constantly analyse the behaviour of other people. Whatever emotions are surrounding you, your body will be subconsciously mimicking them and impacting your emotions. For some people this is more extreme than others, which is why during a sad movie scene not everyone will start sobbing with the main characters. Behavioural mimicry is a trait that helps humans subconsciously bond.

Mimicking someone's emotions increases a person's sympathy

NEXT ISSUE ISSUE 183 ON SALE 26 OCT 2023

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WHY TIES?

Dear **HIW**,
People wear ties for formal occasions, but what makes a tie look smart? And when did people start tying material around their neck to dress up?
Jen Wiseman

The original necktie emerged in the 17th century as a military uniform in Croatia, but the original version was not the same style as today's. These early ties were shorter and were used to keep shirts securely closed. They were bright in colour to capture the attention of the king. It also caught the eye of royalty across Europe. The tie was soon adopted among the French, becoming a popular fashion accessory. This is when ties evolved into the longer, more modern versions that are common today. As ties were inspired by military formal dress, they continued to be associated with formal wear. Originally, black ties were worn for evening events and white ties for daytime events.

The tie was originally called a cravat

The Burj Khalifa is almost double the height of the Empire State Building

TALL TECHNICALITIES

Dear **HIW**,
The Burj Khalifa is impressively tall, but how long would it take to get out in an emergency? Is it wise to have such a tall habitat?
Craig England

The Burj Khalifa in Dubai is the tallest building in the world at 830 metres. As you have mentioned, such an outstanding structure comes with potential safety risks to navigate. Like all buildings, the Burj Khalifa has an emergency exit strategy, which is tailored to its unique height. In the event of a fire, people trapped near the top of the building can enter refuge rooms. The building has a pressurised, air-conditioned refuge area on every 25th floor. This gives people a space to breathe if they run out of oxygen and keeps them protected from flames until they can be rescued.

WE ASKED YOU

This month on social media, we asked you:

Do you have any green home energy technology?

@JEANMCDOUGALL8333

Energy-saving light bulbs

@DOODLENEWS

I recently got draught-proofing on the windows and notice lower energy use

KAYLEIGH PREECE

I have solar panels installed and solar lights in the garden

ROSS RIGGS

Smart plugs so I can be alerted if I leave devices plugged in

@MAIA_H3

I have smart lights so I can switch them off from my phone if I forgot when leaving the house

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HOW IT WORKS

Future PLC Quay House, The Ambury, Bath, BA1 1UA

Editorial
Editor **Ben Biggs**
Senior Art Editor **Duncan Crook**
Production Editor **Nikole Robinson**
Senior Staff Writer **Scott Dutfield**
Staff Writer **Ailsa Harvey**
Group Editor-in-Chief **Tim Williamson**

Contributors
Joanna Elphick, Stephanie Pappas, Andrew Jones, Sascha Pare, Megan Shersby, Robert Lea, Elizabeth Howell, Kiley Price, Emily Cooke, Jennifer Nalewicki, Nicoletta Lanese, Dr Lucie Green, Alex Dale

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Account Manager **Jagdeep Maan**
jagdeep.maan@futurenet.com
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Advertising Sales Director **Lara Jaggon**
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FAST FACTS

Amazing trivia that will blow your mind

BEES CAN RECOGNISE THE FACES OF THEIR BEEKEEPERS

$2 MILLION A DAY

GPS is free, but costs nearly $1 billion a year to run

34

Some species of leech have more than 30 brains

1974

The first barcode was scanned 22 years after it was invented, in 1952

EIGHT HOURS

The first photograph in 1826 took one-third of a day to expose

International Space Station astronauts change their underwear every four days

1,760

In 2010, the US Air Force built a supercomputer out of hundreds of Playstation 3 consoles

15 METRES

Rats can fall from a five-storey building without injury

IN 1760, A FRENCH COLLEGE CLASSIFIED THE BEAVER AS A FISH

225 TO 230

Mathematician Terence Tao has the highest IQ in the world

© Getty

IF I HAD SOMEWHERE TO LIVE...

I COULD GO ANYWHERE IN LIFE

When Abi's mum died, life got tough. She didn't get on with her dad and the arguments became violent. Abi felt her only choice was to leave home. With just the clothes on her back, and no idea where to go, she ended up sleeping on the streets in the freezing cold.

Right now, you could give a homeless young person like Abi somewhere to start their future

Abi's life changed when she was given a room at Centrepoint. A safe place to sleep and recover. A place to develop the skills and confidence she needed to rebuild her life – and leave homelessness behind for good. Now, Abi believes she can go anywhere.

Thousands of homeless young people like Abi are desperately trying to find their place in the world – but first they need a place to start again. **You could help right now by sponsoring a room at Centrepoint for just 40p a day.**

We know this support changes lives. 88% of the young people we help move on positively in life. So please, help someone like Abi today. Thank you.

Text PLACE to 78866 to donate £3
Call free on 0800 472 5798
Visit centrepoint.org.uk/place
Or complete and return the form below

SPONSOR A ROOM. HELP A HOMELESS YOUNG PERSON FIND THEIR PLACE.

YES, I WANT TO SPONSOR A ROOM FOR £12 A MONTH

Please collect my payment on the 1st/15th of every month (please circle preferred date).

Instruction to your Bank or Building Society to pay by Direct Debit

To the Manager:
Name and full address of your Bank or Building Society:

Originators Identification No. 6 5 9 1 0 7

_____ Postcode _____

Name(s) of Account Holder(s) _____

Bank Sort Code: ☐☐-☐☐-☐☐ Account Number: ☐☐☐☐☐☐☐☐

Instructions to your Bank or Building Society: Please pay Centrepoint Direct Debits from the account detailed in this instruction, subject to the safeguards assured by the Direct Debit Guarantee. I understand that this instruction may remain with Centrepoint and, if so, details will be passed electronically to my Bank/Building Society.

Signature(s) _____ Date _____

Banks and Building Societies may not accept Direct Debit Instructions for some types of account.

Increase your donation by 25p for every £1 you donate with Gift Aid giftaid it

☐ By ticking this box I confirm I am a UK taxpayer and want Centrepoint to Gift Aid all donations I've made in the last four years and any donations I make in the future until I notify you otherwise. I understand that if I pay less Income Tax and/or Capital Gains Tax in any tax year than the amount of Gift Aid claimed on all my donations it is my responsibility to pay any difference.

Your name and address are needed to identify you as a current UK taxpayer.

Your donation will go towards funding Centrepoint's vital work with young people all year round providing accommodation and support. We sometimes use models and change the names of the young people we work with to protect their identity; however all stories are true and as told by the young person.

Full Name: _____
Address: _____
Postcode: _____ Telephone: _____
Email: _____

Thank you for donating to Centrepoint today.

We'd love to show the impact of your support and share how young people continue to need your help, through newsletters, fundraising appeals and information about events. Please let us know how best to stay in touch with you by adding your details above, and ticking the relevant boxes:

☐ **Please contact me by email** ☐ **Please contact me by phone**

Last year our supporters helped us change the lives of over 15,000 homeless young people. By letting us know we can count on you, we can continue helping young people with a home and a future.

Your privacy is key.

We promise never to sell or swap your details, and will always keep them secure. You can view our Privacy Notice in full at www.centrepoint.org.uk/privacy. You can opt out of post and change how we communicate with you at any time. Please call 0800 232320 and speak to one of our friendly team or email supportercare@centrepoint.org to do this and ask us any questions.

Please return this form to: Freepost Plus RTXY-LBEA-UTJJ, Angel Fulfilment Services Ltd, Communication Centre, Par Moor Road, Par PL24 2SQ.

Registered office address: Central House, 25 Camperdown Street, London E1 8DZ. Company no. 1929421. Registered Charity no. 292411. Housing association no. H1869. VAT registration no. 649 345 018.

Registered with FUNDRAISING REGULATOR

centre point give homeless young people a future

Registered Charity No 292411.
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